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TRACKING TRAINING V: FIELD STUDY OF THE TRAINING EFFECTIVENESS OF THE GENERAL VEHICULAR RESEARCH TOOL

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ABSTRACT

TRACKING TRAINING V.: FIELD STUDY OF THE TRAINING EFFECTIVENESS OF THE GENERAL VEHICULAR RESEARCH TOOL

A tracking training research apparatus received initial evaluation in two field training situations. A group of primary flight students who received a portion of their training on this apparatus were 11% more proficient than a group without such training in terms of a flight rating measure. A group of submarine personnel given training on the research device were compared with a group given training on a specific simulator. Those trained with the research device did about one-half as well as the other group in controlling the simulator. These results are discussed and recommendations for equipment modifications and further experimental use are presented.

FOREWORD

Purpose

This report describes the results of the most recent of a series of studies directed at identifying methods for the development of vehicular tracking skills. Earlier reports in this series are identified in the Bibliography on pages 45-46 by the following citation numbers: 3, 7, 12, 13.

The purpose of the study reported here was to perform an initial field test of the effectiveness of a general vehicular research tool (GVRT) designed according to earlier laboratory findings in this program. This research tool embodies the concept that the skill associated with the control of a given vehicle is in substantial part a general one which can be developed to a large extent with a training system not specifically representing any single vehicle.

This field study involved the following two experiments:

1. A comparison of two groups of flight students one of which received practice on the GVRT in addition to the regular flight courses, the other of which did not receive such additional training.

2. A comparison of the performance of two groups of submarine school students on a complex specific simulator after one group had received GVRT training and the other training on the simulator itself.

Results

At the Aviation School the following results were obtained:

1. When a special rating form for flight proficiency (adapted specifically for this study from an HumRRO form) was the criterion, the group with GVRT training was significantly superior to a group without such training on final check rides for both instrument and contact flight. This difference was about 11%.

2. Students who passed the course performed significantly better on the GVRT than did those who failed.

3. There was no significant difference between experimental and control groups during 14 progress check rides when measured by the special form.

4. The groups did not differ with respect to (a) progress and check ride performance when measured by the regular rating form for flight proficiency (the official school form), (b) time to solo, and (c) Link Trainer scores.

5. The attitudes of students and instructors toward the GVRT as a training device were mildly favorable.

The Submarine School results were:

1. Length of practice on the GVRT (45 minutes a day or 60 minutes a day for 11 days) did not affect performance.

2. Performance of the GVRT trained group was significantly inferior to the performance of the simulator trained group when both were tested on the simulator.

3. The GVRT group, when transferred to the simulator task, did about half as well as the simulator trained group. The transfer effects were positive, however, because the GVRT group was 45.8 percent better than it would have been without GVRT training.

4. The attitudes of the students to GVRT training were highly favorable.

Implications

The two field studies reported here must be regarded as exploratory in nature. They were conducted on a "not to interfere with regular training" basis on very small samples. This was done in the belief that a pilot field effort would yield data on which to base certain modifications of the research equipment, and further evaluations over longer periods of time with larger samples. The results of these experiments have met this objective and the following implications are drawn:

1. The principles embodied in the GVRT appear to be sound. Practice on a device of this sort does enhance performance in a specific vehicle.

2. However, the general skill developed by this device is difficult to isolate fully from the specifics of a given task. When these specifics conflict (in the training and operational situations) the gains from developing the general skill are at least partially obscured. Therefore, a given application may require some special provisions for display and control features.

3. The lack of "face validity" makes acceptance by training personnel difficult.

4. This research tool with some minor modifications (probably to include "adaptive" circuits) should undergo a relatively long term trial in an on-going training situation.

5. There is some indication that a device requiring the continuous control of system dynamics of this sort may also prove useful in personnel selection. The utility of such application should be explored.

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I. RECOMMENDATIONS

1. The General Vehicular Research Tool is recommended (with modifications in certain instances) for inclusion into training programs for the control of vehicular and dynamic systems on an experimental basis.

2. A minimum of five and if possible more hours of training on the General Vehicular Research Tool should be included early in the training program; half-hour to one hour sessions are recommended.

3. The General Vehicular Research Tool may be used as a partial substitute for specific trainers. When such use is made, early training may be restricted to the General Vehicular Research Tool followed by a training program combining both general and specific training experience.

4. Further studies should be conducted to investigate the potentiality of the General Vehicular Research Tool as a selection instrument.

5. Modifications (as recommended in the text) should be considered and implemented as circumstances may indicate.

II. BRIEF OF STUDY

A. Introduction and Review

1. The General Vehicular Research Tool (GVRT)

This study reports the field evaluation of a research instrument which has been developed as a result of a series of studies (3, 7, 12, 13) on the principles of transfer of the psycho-motor skill used in controlling dynamic systems, especially vehicles.

The principal interest throughout the studies has been training men to control dynamic systems, such as vehicles, and the research apparatus developed during the studies is aimed at teaching vehicular control skills. The research apparatus is called the General Vehicular Research Tool (hereafter referred to as the GVRT), and it constitutes what is believed to be a new departure in practical training devices. The break that it makes with tradition is that it does not attempt to simulate anything in particular.

2. Simulator Design and Transfer of Training

Vehicular training devices have been designed traditionally on the principle that they should simulate the operational system as faithfully as circumstances will allow. This common sense approach rests upon the assumptions that the closer the training device resembles the operational equipment the higher will be the degree of transfer, and that skills are specific to particular tasks and consequently that training devices must also be specific. These assumptions have led to an increasing specificity of training devices with the result that they have increased in number, become more complex as fidelity of simulation has increased, and have cost more.

This approach is not without scientific support. Various authors have drawn attention to the need for specific simulation. Briggs and Wiener (4) have demonstrated the importance of accurate simulation of proprioceptive cues ("stick feel") in order to achieve substantial positive transfer from a training to a real situation. Muckler, et. al. (17, 18, 19) have shown the importance of the accurate rendering of certain long-period oscillatory transients in aircraft simulation; their work also indicates the need for accurate rendition of the rate of onset of transient effects and, in general, of the level of complexity of the system.

While this work has drawn attention to the desirability of accurate replication of certain particulars in the simulation, other

researches have demonstrated that transfer of skill can take place between different dynamic systems. Briggs, Fitts, and Bahrick (5) have shown that when subjects were trained on a single integration tracking system and then transferred to a double integration tracking system, up to 68% positive transfer could occur dependent upon the number of practice trials prior to transfer. Holland and Henson (10) showed that positive transfer occurred when switching either from unquickened to quickened control systems or from quickened to unquickened control systems. Dependent on the amount of training on the practice system, they found that positive transfer ranged from 46% to 64%. Newton (20) has demonstrated that when the fidelity of simulation of submarine control dynamics was reduced to a point where the simulation was a relatively simple linear approximation to the actual dynamics, very little loss of training occurred. This result, it may be noted, is in apparent opposition to the findings of Muckler, et. al., for the simpler simulations of the submarine did not contain the elements of complexity which Muckler et. al. determined to be important.

Birmingham and Chernikoff (1) have also found strong positive transfer effects when subjects were trained on a zero order control system and transferred to a third order control system. They conclude their discussion of the transfer effect with the statement that "it would appear that the time required to learn to handle a specific vehicle might be greatly shortened if the trainee's basic ability to equalize [1] higher order systems were developed to a high degree."

These latter researches indicate that there may be a general component of skill which is common to many (perhaps all) complex control tasks. Support for this viewpoint may be drawn from the work of Fleishman (8). He has worked on "the other end" of the problem; namely, he has attempted to identify the skill factors, generally of a fairly specific kind, which form the components of performance on complex control tasks. He has found numerous factors (he has differentiated 15 separate factors by factor analysis) which, however, in sum account for not more than 26% of the total variance in tracking performance on a complex task. Fleishman suggests that the unaccounted variance may be associated with central factors related to predictive capability. This suggestion, in our view, has considerable merit for it suggests the analogy to a servo-mechanism whose efficiency would be closely linked to its phase advance characteristics.

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[1] Birmingham and Chernikoff use the word "equalize" as a close equivalent to the word "control."

Early in the studies preceding the present one it was proposed that tracking skills are not entirely specific to particular systems, but include both general and specific components (12). The general component was demonstrated in laboratory studies where, when the display and control elements of the simulator were constant, wide variations of the system equations in the computer did not affect relative tracking skill to any significant degree. The finding that control skill was highly transferable from one system to another afforded the necessary rationale for the concept of a generalized trainer. Control skill developed on such a trainer, it was hypothesized, could be transferred to any number of operational systems.

Further laboratory work confirmed the validity of the concept (13). It was shown that training on a certain dynamic system was not necessarily the best method for developing skill on that system. Especially when the specific system in question was complex, training on that system from the outset was inferior to training on other systems. It was shown that for a particular two-dimensional unstable control system, the worst method of training of several employed was to start the students at the outset on the criterion system. The best method of training was to use a generalized but simple simulator which practiced the students on a variety of systems of varying characteristics and difficulty. In general, it was found that this form of training, designed to develop a general skill by practice across a wide range of dynamic systems, appeared to be the most advantageous way to prepare a man to eventually master some specific complex system. This finding is in agreement with the suggestion of Birmingham and Chernikoff concerning the effectiveness of generalized training which has been quoted previously.

The studies indicated that one of the most important aspects of system dynamics appears to be the stability of the system. Stability depends upon the strength of the feedback terms which tend to null errors automatically with respect to system output or the derivatives of system output. Variation in stability, therefore, varies the balance between the onus on the man and the onus on the machine for nulling errors.

It was found that training programs incorporating practice on systems of varying stability were effective training programs. The over-all conclusion was drawn that general tracking training, incorporating as a primary element practice on systems of varying stability, increases skill for the eventual control of any system and is most useful as a preparation for the control of complex systems.

This work gave promise for the utility of a generalized vehicular training instrument. However, it was recognized that all control skills have specific, as well as general, components. A generalized trainer cannot provide sufficient training for the immediate control of any real system. Any real system has idiosyncratic features of display, control, and dynamics (e.g., attitude indicator, stick feel, dynamic non-linearities) which can be learned only on the real system or on a specific simulator. Some of these specifics may be of primary importance in the learning of a skill as Briggs and Wiener and Muckler, et. al. have shown. Furthermore, a generalized trainer does not provide the appropriate environment for any real control task, nor will it teach the procedural skills which often must be carried out simultaneously with control actions. These aspects of control skills also must be taught in high fidelity simulators or in the actual vehicle.

These limitations are not invalidating, but rather define the skill which a generalized psycho-motor trainer is designed to teach, namely, the general skill of acting as the transfer element between the displays of system output (and the derivatives of system output) and the control stick.

3. The Nature of the General Skill Factor

We postulate that this general skill is associated more with central cognitive factors than with peripheral sensory or motor factors. Its primary component may be the ability to synthesize information from the displays and to transform it into the form of predictions to guide the following control actions. It should be recognized that, while the empirical evidence is fairly strong for supposing some such general factor, our theoretical understanding of the nature of the general factor is quite inadequate. It may be that generalized training is effective because it instills a correct set to learn (e.g., 9, 15, 16). Alternatively, generalized training may be effective because the generalized training program includes some of the specifics of later tasks and the individual is able to select from his repertoire of elemental skills the particular ones necessary to solve a present requirement. A further possibility is that generalized training is effective because it permits a more gradual build up of skill and does not confront the individual exclusively with a control task which he may find initially very difficult.

Parallel with these considerations are considerations of motivation. We have suggested that some part of the effectiveness of a generalized trainer may lie in its ability to maintain a balance

between challenge and accomplishment (13). Because the system dynamics are variable, the individual can be set problems which are ahead of his contemporary skill and thereby maintain a goal to be achieved, and at the same time be set problems within his contemporary skill and thereby have maintained his sense of achievement.

None of the above suggestions are mutually exclusive or, in our view, uniquely compelling. At the present time they are offered as hypotheses, either singly or in combination, which merit future investigation.

4. The Need for High Level Psycho-Motor Skills and for Their Training

Researches on training of psycho-motor skills inevitably become involved with the issue of man and machine allocation for control functions. The issue, in general terms, is whether training men to do relatively complex tasks is a proper and efficient way to use the human resource.

It is widely recognized that the use of complex simulation devices to train men to high skill levels has serious disadvantages. The important disadvantages are:

- It is seldom possible to build a true simulation of a complex system; hence, all trainers are to some extent "part-trainers" and training has to continue on the real vehicle.

- Trainers are seldom available at the same time as the system becomes available, hence, there is an interim period when training can be accomplished only on the real vehicle.

- Specific trainers become obsolete as the operational system becomes obsolete (and the life time of systems is shortening).

- The costs of trainers are high and increasing; they also tend to be large, require special facilities, and to require a fair amount of maintenance.

- The student is faced at the outset with the full complexity of the task.

The GVRT is seen as a partial answer to these objections. Potentially it is able to train men (at least in part) to high skill levels without the costs and penalties associated with the more complex and specific training devices. The GVRT does not attempt true simulation but relies on transfer of training for its effectiveness; it does not set out to simulate an entire system and the need is recognized for limited use of more elaborate trainers; it will be available for any system at any point in that system's development; it will not become obsolete; its cost is low; and it allows for the progressive build-up of skill.

Assuming that the utility and effectiveness of the GVRT can be verified, its acceptance into training programs may exert considerable influence on the design principles which have been promulgated for man-machine design. One design principle, proposed by Birmingham and Taylor, is that of "stimulus-response integrity" (2). This principle asserts that human tasks should be simplified so that, in the case of man-machine control loops, the man is operating as a zero-order element. However, and as stated in the first report of this series (7), "simplification of the task of the human element in a tracking system usually results in the complication of the mechanical parts of the system."

The principle of "stimulus-response integrity" should give ground, in our view, to a principle of "skill utilization;" namely, that the skill potential of a man should be used whenever there are no contra-indications deriving from system considerations.

There are, of course, numerous instances where system goals can be best served by automated control elements; or alternatively by simplifying man's control tasks and retaining him in order to monitor the system and be available for immediate back-up control. These cases are examples of design flowing from system considerations and the viewpoint that we wish to advance is that man's skill potential should not be discounted in system design. Where it can be shown, as in this project, that humans can control third to fourth order systems effectively when sufficient training is given to them, it will often be wasteful not to use this resource. Any final decision on this issue however, must depend on the compatibility of the level of skill obtainable by man in relation to system criteria.

In summary, our viewpoint is that the GVRT is potentially a powerful but inexpensive tool for realizing the skill potential of

men and hence should help to discourage needless efforts directed at over-simplifying their tasks. [1]

5. Principles Governing the Design of the General Vehicular Research Tool

As work progressed through the various phases of the project, a set of principles was developed and these principles were used to determine the design of the GVRT. These principles will now be summarized; the reader is referred to the earlier reports for a more detailed account and for their justification (3, 7, 12, 13).

(1) There is hypothesized to be a general component of skill in controlling dynamic vehicular-like systems which, once acquired, is transferable from one system to another.

(2) Generalized experience of being a control element in various dynamic systems provides useful basic initial training for a person learning to control a specific complex system.

(3) No exact simulation of an operational system is required in order to achieve a large proportion of the skill required to control that system; the training device can be built as a minimal representation of the motions of generic vehicles moving through space with consequent minimization of construction costs and complexity. However, final training must include practice on the specific system and its idiosyncratic features.

(4) The primary ingredient of a successful training program for the development of psycho-motor skills is practice at control tasks.

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1 The operational experience with manned space vehicles is interpreted as vindicating this view. The Mercury flights have demonstrated the control capabilities of trained men with the consequence that future space capsules will rely more heavily upon man's capabilities; various automatic control devices will be either eliminated or simplified.

(5) Intellectual understanding of control dynamics is of little or no help in developing skill to control a dynamic system. However, instruction can be useful when it develops a proper orientation and attitude towards the task and which, in appropriate cases, gives "rules of thumb" for performing the task.

(6) Experience on various dynamic systems (particularly systems of variable stability) as in 2 above, provide a proper balance between challenge and accomplishment.

(7) Consequent to the above, adequate provisions must be made to feedback performance scores.

The GVRT was designed to implement these principles. A complete description of the prototype GVRT may be found in a previous report (3).

B. Field Studies

1. Introduction

Two field studies were conducted.

In the first study, training on the GVRT was given to flight students at a primary fixed wing flight school. The GVRT was additional to the regular training curriculum. The purpose was to determine the increment in proficiency that would occur by practice on the GVRT.

In the second study, the GVRT was compared to the Skipjack submarine simulator (Basic High Speed Submarine Control Trainer, Device 21B56) at the Submarine School. One group of students undertook training on the GVRT while another group undertook training on the Skipjack simulator. The performances of the two groups on the Skipjack simulator were compared with the purpose of determining how well the GVRT could be substituted for the more specific and complex Skipjack simulator.

Both studies were conducted on a non-interference basis, which meant that no student at any time could have his regular school curriculum or other duties interfered with. This restriction forbade alternative plans which might have put the GVRT to more stringent test; however, the studies as designed provided for initial tests of the validity of the GVRT.

2. The General Vehicular Research Tool Equipment

The GVRT was designed to be a tracking training research apparatus and was officially designated by the USNTDC as the Tracking Training Research Tool, Device X 11H42. Figure 1 is a photograph of the GVRT while Figures 2 and 3 are photographs of the student's and instructor's panels.

The student's panel shows vertical and horizontal positions and motions. The oscilloscope shows the vehicle's position relative to a line in space which the vehicle is assumed to be moving along and is termed system output. The meters to the left of the oscilloscope show derivative functions of the vertical component of system output, namely, pitch angle, pitch angle rate, and control element (elevators or planes) position. The meters above the oscilloscope show derivative functions of the lateral component of system output, namely, heading angle, heading angle rate, and control element (rudder) position. A speed indicator occupies the position above and to the left of the oscilloscope. The three meters on the left indicate the integrated absolute error score ($\int |e| \, dt$) obtained during a problem; the top meter shows integrated error for the lateral (horizontal) dimension, the next meter shows integrated error for the vertical dimension, and the bottom indicator shows combined integrated error obtained by comparing continuously the lateral and vertical error and summing whichever is the larger. All errors were computed with reference to the center point of the oscilloscope display, and the operator's task was to bring the spot to center and to hold it there.

The instructor's panel enables the setting of a "problem."

The column of controls on the left enables the establishment of the responsiveness of the vehicle to stick input by (from top to bottom):

. response rate	Variation in the angular accelerations imparted by control and element position.
. stick lag	Variations in the time constant of the exponential lag between stick position and control element following.
. pitch-speed couple	Variations in the degree to which speed is varied as the pitch angle of the vehicle is varied (gravity effect).

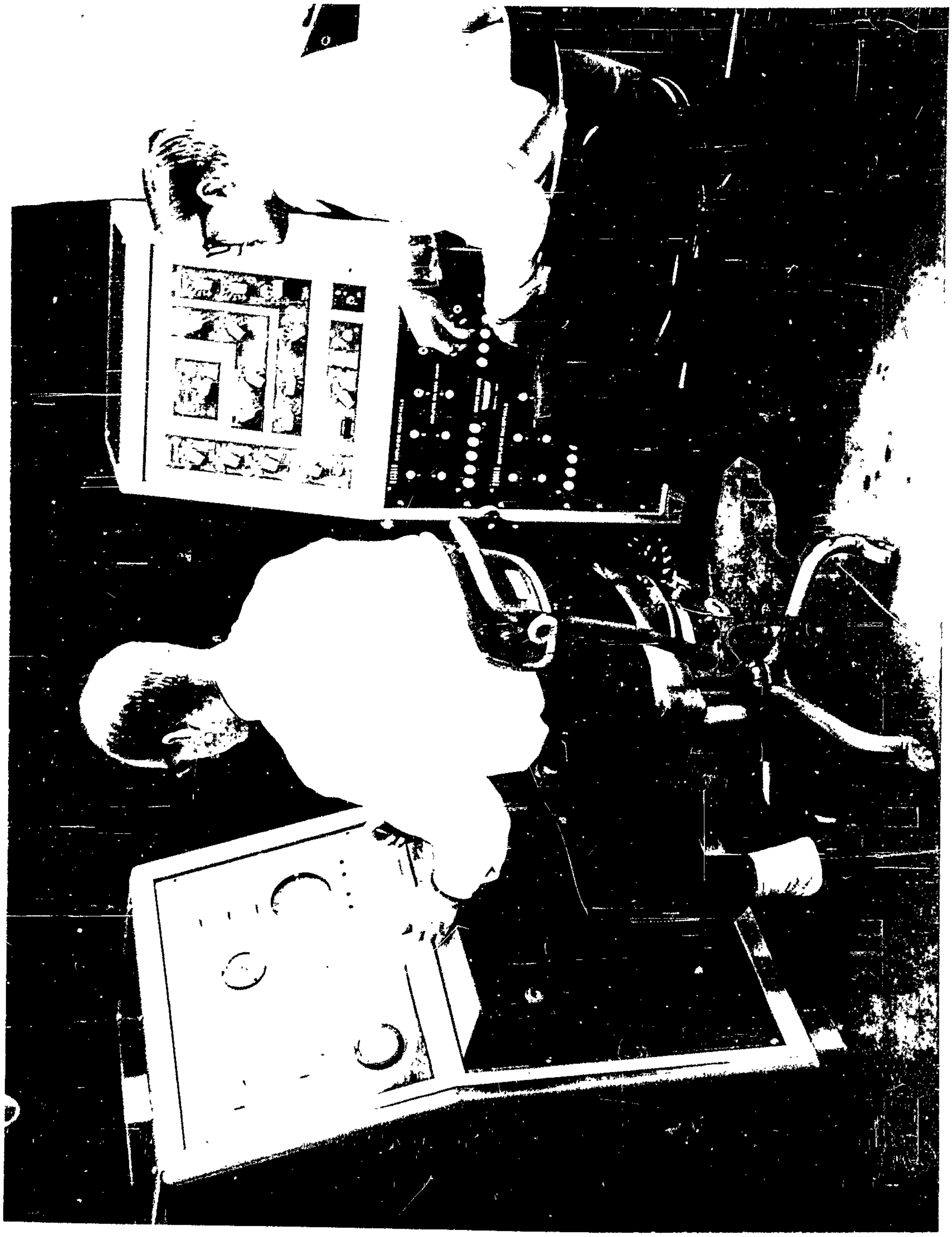

Figure 1. The General Vehicular Research Tool

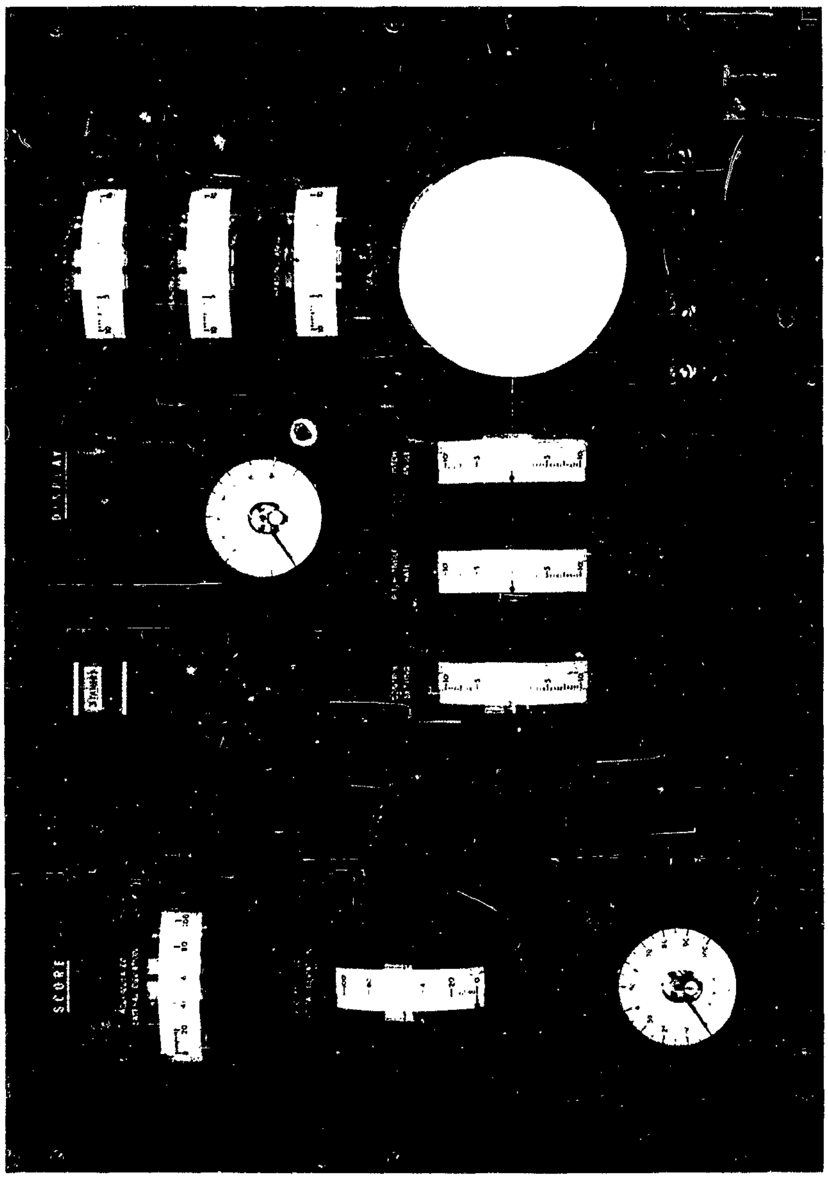

Figure 2. The General Vehicular Research Tool:
The Student's Panel

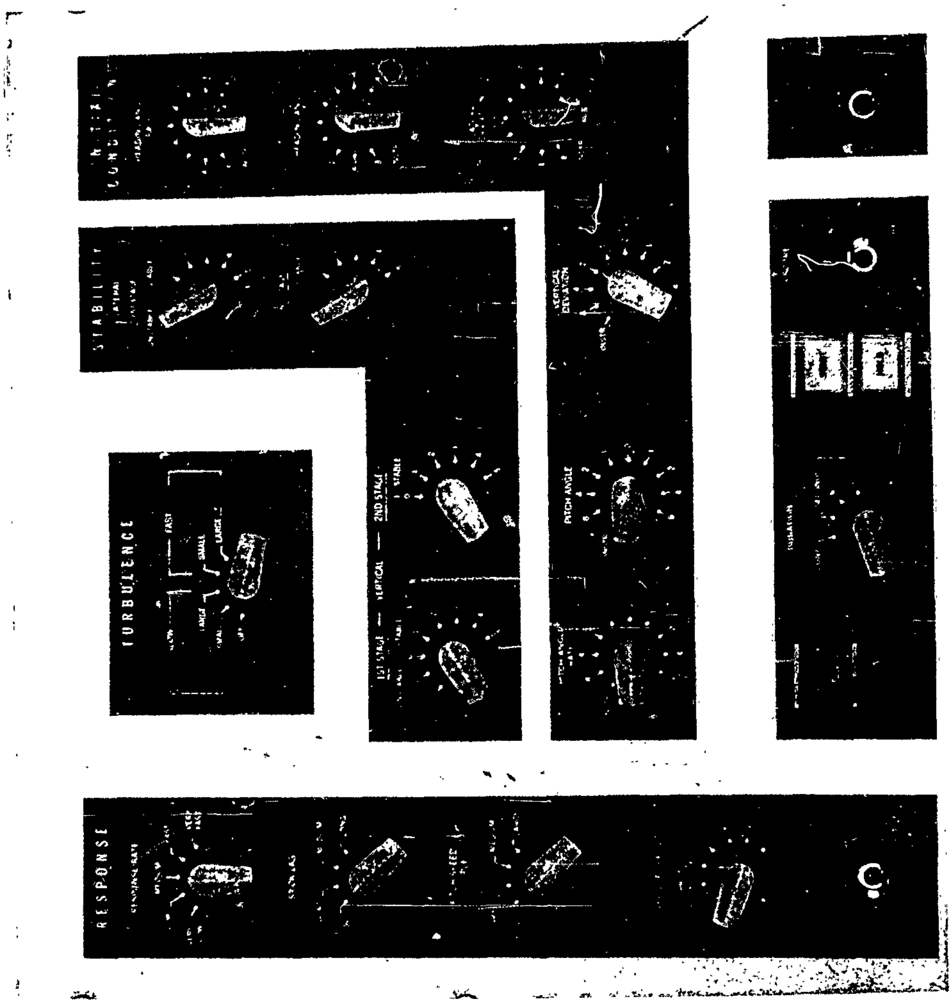

Figure 3. The General Vehicular Research Tool:
The Instructor's Panel

. vehicle speed — Variations in the speed (arbitrary units) of the vehicle.

Stability controls of the "1st stage" determine the gains in the feedback loops representing angle-rate dampings, i.e., an angular acceleration proportional to the rate of change of pitch or yaw. (Damping is a somewhat inappropriate term, since feedback may be either positive or negative.) Controls of the "2nd stage" determine the gains in feedback loops representing angle, i.e., pitch or yaw, which produce an angular acceleration term proportional to pitch or yaw. This second order stability term is always negative (stabilizing) when employed in the trainer.

The control labelled "Turbulence" enables the introduction of various degrees and kinds of forcing functions.

The L-shaped set of six controls labelled "Initial Conditions" enables the pre-positioning of any or all of the instruments showing angle-rate, angle, and vehicle position terms.

The controls at the bottom of the panel are operating controls enabling problem Start, Hold, and Reset; selection of scoring On or Off; and selection of speed control by Pre-Set or Throttle (speed controlled by throttle on left hand of operator.)

3. Study 1: Flight School Evaluation

a. General Plan

The Flight School teaches junior officers [1] of the Army to fly [2] light single-engined propeller aircraft. [3]

[1] The majority of students are Lieutenants in their early 20's. Some older men, who may hold ranks up to Colonel, are occasionally enrolled. Officers from Allied countries also are occasionally enrolled.

[2] The instruction at Primary School is aimed to give over-all pilot competence and airmanship. The destination of most of the students is to Army Air Cooperation Units and emphasis is given at the Primary School to low altitude flight, maneuvers and navigation.

[3] The aircraft used for instruction is the Cessna L-19 "Bird-Dog", a light high-wing monoplane. This aircraft is an early type of Army Cooperation airplane.

The research design had the following general form:

	Training Treatment	Criterion Tests
Control Group	A (Regular Curriculum)	B
Experimental Group	A+ A' (Regular Curriculum plus GVRT Training)	B

The regular curriculum at the school lasted for 17 weeks of full-time participation. It consisted of approximately 120 hours of flying, including about 20 hours of instrument flight, and ground school. About 10 hours of Link training was included.

The experimental group undertook, in addition to the regular curriculum, GVRT training over the first nine weeks of the course, so that each man received approximately one hour of manual control of the GVRT per week. One hour per week was also spent watching another man at the controls. Due to the requirement of non-interference, GVRT training occurred in the period allocated for flight but in time periods before, after, or between flights when the student had no scheduled duties.

The experimental and control groups consisted initially of 16 men each, and the groups were matched.

A measurement of flying proficiency was used to assess the effectiveness of the training programs.

This plan has the disadvantage that the experimental group receives extra training over the control group and if the extra training has any value, however slight, it would be expected to push the experimental group ahead of the control group on the criterion measurement. However, as previously noted, the GVRT training occurred in times which otherwise would be unfilled. The experimental plan, therefore, is addressing itself to the question of whether additional GVRT training provides some advantage and is a beneficial way to fill otherwise wasted time periods. It should be noted, in addition, that due to the ease of transportation, small size, and low power requirements of the GVRT it can be taken to almost any place that students might be; it does not suffer the disadvantages of many other training devices (which could be thought of as competitors of the GVRT for the same gaps in the student's schedules) which by reason of their size, etc., are static and require a permanent installation to which students must go for practice.

A secondary capability of the experimental plan is to provide some indication concerning the potential utility of the GVRT as a selection instrument. The students in the experimental groups undertook tests on the GVRT, and the results of these tests were examined for their utility in distinguishing between the students who passed and failed the course.

b. Selection and Matching of Subjects

Of the total group of 48 officers who were enrolled initially in the course, two groups of 16 officers each were selected to form the experimental and control groups.

The total group was screened first for:

- no previous pilot experience
- no rank higher than lieutenant
- age between 20 and 30 years

Biographical data on each man were collected consisting of:

- marital status (married or single)
- age
- education
- AFWAB Score: Army Fixed Wing Aviation Battery: general abilities test related to flying proficiency.

For data indicating the relationship of these characteristics against failure at Flying School see Appendix A.

These four criteria provided a profile and the procedure was to find two men who had as nearly as possible the same profile. It was found possible to obtain matchings with the exception of marital status. One man of each pair was allocated to the experimental group, the other to the control group. The over-all group matchings on the four criteria are listed in Table 1. The top half of the table gives data for the initial groups while the bottom half shows the same data for the students who successfully completed

flight training. The original groups of 16 subjects each were reduced to 9 in the experimental group and 10 in the control group.

Table 1. Comparison of Experimental and Control Groups on Background Profiles for a. Initial Groups and b. Final Groups

a. Initial Groups

Group	N	Marital Status	Mean Age	Mean Education	Mean AFWAB Score
Experimental Group	16	56% married	25.1	15.0	57.7* (a)
Control Group	16	81% married	24.6	14.8	57.4

b. Final Groups

Group	N	Marital Status	Mean Age	Mean Education	Mean AFWAB Scores
Experimental Group	9	68% married	25.0	14.7	64.9* (b)
Control Group	10	90% married	24.3	14.9	59.9

* Due to one individual's AFWAB Score being unavailable the averages are based on, for (a) 15 cases and, for (b) 8 cases.

The drop-outs from the course affected the analysis of the results, for they had the result of progressively diminishing the group sizes. Table 2 documents the incidence of drop-outs.

c. Experimental and Control Group Schedules

The experimental and control groups undertook identical flying training and testing schedules. Over the 17 week course each student flew a total of up to 120 hours to which 20 hours were instrument flight. The range of total flying hours was 110 to 120 hours.

Table 2. Incidence of Drop-Outs

	Experimental Group			Control Group		
Week of Course	No. of Drop-Outs During Week	Reason	No. Remaining at end of week	No. of Drop-Outs During Week	Reason	No. Remaining at end of week
1	0		16	0		16
2	0		16	0		16
3	1	Medical	15	0		16
4	1	Flying Deficiency	14	1	Flying Deficiency	15
5	0		14	2	" "	13
6	0		14	2	" "	11
7	2	" "	12	0		11
8	0		12	0		11
9	0		12	0		11
10	0		12	0		11
11	0		12	0		11
12	1	" "	11	0		11
13	0		11	1	Medical	10
14	2	1 Medical 1 Flying Deficiency	9	0		10
17	NO MORE DROP-OUTS					

Each student flew on most available flying days, sometimes twice a day. A student did not necessarily have the same instructor throughout the course, although this was the usual case. It should be noted that the flying instructors knew whether their students were in the control or experimental groups.

The flying program conformed to traditional patterns. First instruction was given concentrating on simple maneuvers, takeoff, landing, and the basic procedures. After soloing, the student had a mixture of solo and dual flights; the instructor progressively introduced new maneuvers and polished the skill of the student on maneuvers already learned. At about the 40th hour of flight, the student received a Contact Check Ride during which his skill was evaluated by special check ride pilots. Instrument flight was then begun culminating in an Instrument Check Ride at about the 100th hour. At the end of the course a second and final Contact Check Ride was given in which the student had to show himself proficient in all the basic maneuvers and procedures of flight. All check rides were conducted by pilots who were unaware as to which students were in the experimental and control groups.

The experimental group received GVRT training through the 9th week of the course which occurred at approximately the 40th hour of flying and with the first Contact Check Ride. Each student received GVRT training twice a week; each session was attended by two students and lasted one hour. In general, each student received instruction and practice through the first 40 minutes of the hour (each student, therefore, receiving 20 minutes of active training on the GVRT while the other watched), which was followed by a Daily Test (10 control problems) given to each student. Other tests given to the students were the Pre-Test and the Major Test. The Pre-Test (5 simple control problems) was given in the first session and was designed to measure the initial level of skill and to diagnose whether any of the students seemed unusually skillful or unskillful; this test was repeated twice, at the times when the Major Test was given, to measure the improvement in controlling simple problems. The Major Test (20 problems of varying types and difficulty) was given half-way through the training and at the end of training; this test was designed to measure the student's proficiency for controlling a variety of dynamic systems. A detailed account of the scheduling and of the training program is given in Appendix B.

d. Criterion Tests

For the purpose of this study, special evaluation forms for measuring flight proficiency were constructed.[1] These forms were called Special Forms and were constructed on the principles that:

- Each evaluative observation must be done with respect to overtly observable behavior.

- Each evaluative observation must be accomplished against an objective criterion.

They consist of items such as "Climbing Turns and Level Off" for which a number of elements are specified, such as Bank 15° (± 5°). For this case the student was instructed to maintain a 15° bank; if he did maintain his bank angle within ± 5° he passed, if he went outside the limits he failed. Each element was, therefore, either passed or failed and was evaluated against an objective criterion metric (in this case the bank angle indicator). The maneuvers incorporated into the Special Forms give a broad cross section of maneuvers which pilots are required to perform, and concentrate on those maneuvers which are basic to pilot competence.

The Special Form occurred in two versions and these are documented in Appendix C. The different versions, the number of maneuvers, and the total number of scored items were as follows:

	Number of Maneuvers	Scored Items
Contact Flight	6	28
Instrument Flight	6	27

[1] We wish to acknowledge the help rendered by Dr. W. Prophet of HumRRO, Ft. Rucker in the preparation of these forms. Dr. Prophet made available to us a previous form which had been used for flight proficiency testing, and with his aid we modified, simplified, and shortened this form to derive our forms. Further development and refinement of the forms was conducted with the help of the flight school instructors.

The Special Forms were administered in two ways:

(1) Progress Rides

Administered to a student within a normal instructional period by the student's regular instructor at the following times:

		Hours of Flight
Contact Flight	-	12 times at 2, 5, 9, 13, 18, 27, 35, 48, 66, 78, 94, 110
Instrument Flight	-	4 times at 54(3), 61 1/2(8), 78(13), 93(19)

(Figures in parenthesis refer to hours of instrument flight)

(2) Check Rides

Administered to a student during a school scheduled check ride by a "check-ride" pilot (a pilot other than the student's instructor).

Contact Flight - No. 1 Check Ride at or about 41st hour of flying.
No. 2 Check Ride between 110th and 120th hour of flying.

Instrument Flight - at or about 98th hour of flying (after 20 hours of instrument flying).

In addition to the above, records were maintained from the regular rating forms used at the school, hours of dual flight prior to solo, and performance on a Link trainer. Students and instructors also filled out questionnaires and were interviewed concerning their opinions of the GVRT.

e. Results and Analysis [1]

1) Analysis of Experimental and Control Group Data on Criterion Measures

a) Figures 4, 5, and 6 show group average performance as measured by the Special Forms.

The data represented on these figures is the data which was retrieved and is incomplete in two respects:

[1] Detailed statistics are provided in Appendix D.

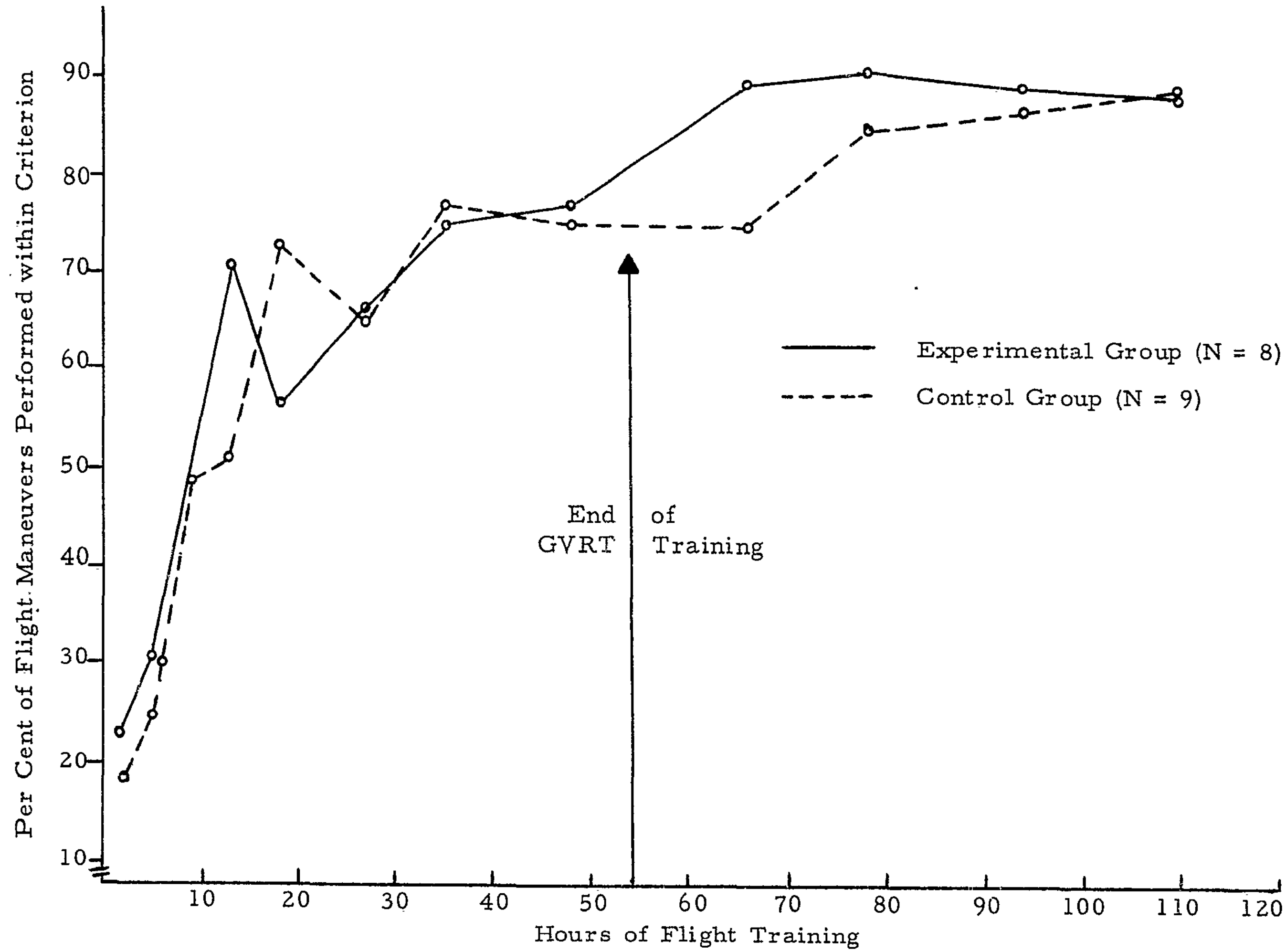

Figure 4. Learning Curves for Contact Flight Proficiency (group average performance measured on special form)

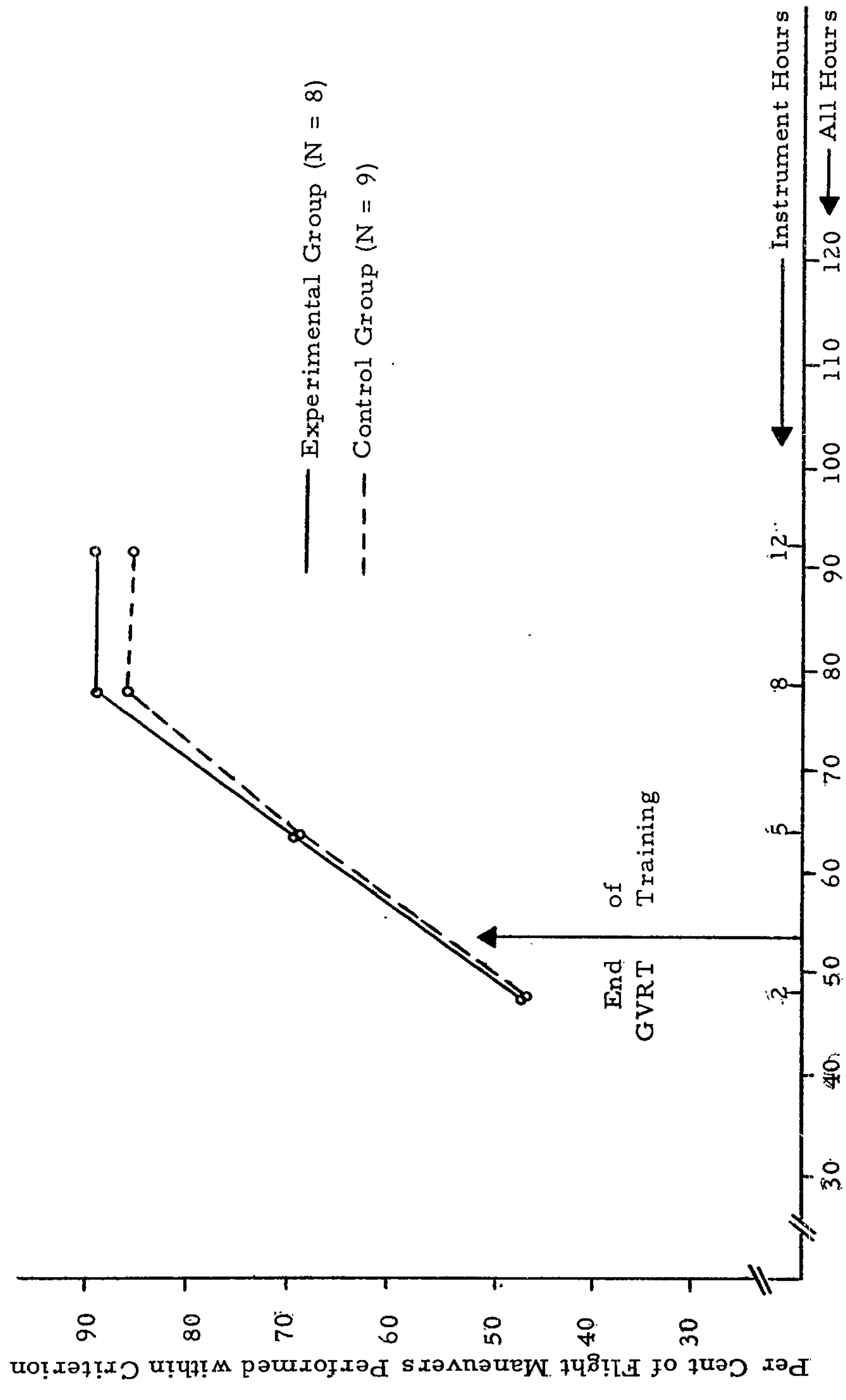

Figure 5. Learning Curves for Instrument Flight Proficiency (group average performance measured on special form)

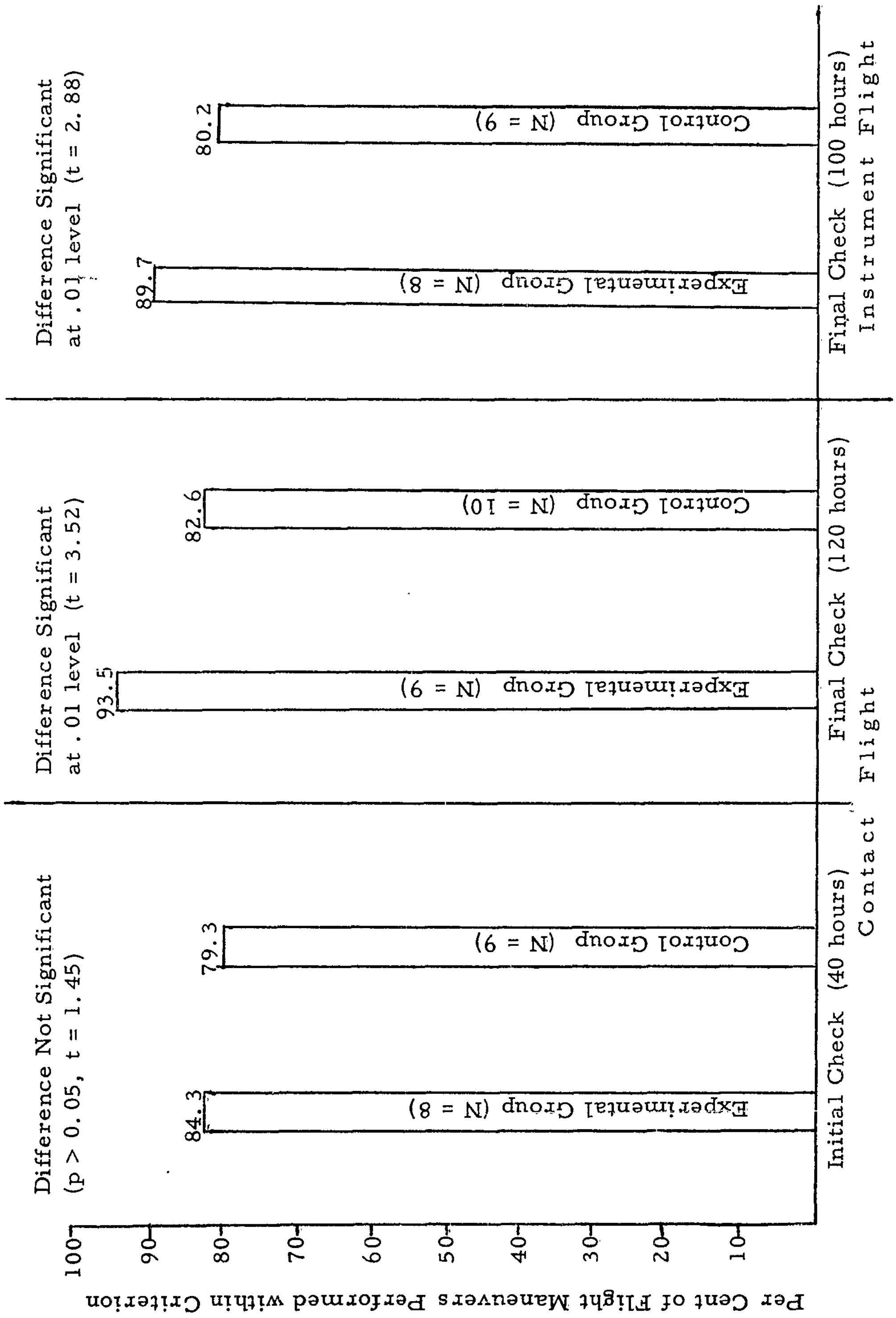

Figure 6. Comparison of Control and Experimental Groups on Check Rides

(1) Number of Subjects. Only the data from the students who finally passed the course were used, which was 9 students for the experimental group and 10 students for the control group. However, we suffered an incomplete return of some of the data on these students. For the progress rides the rating booklets on two students were not completed by the instructors (1 from the experimental group and 1 from the control group), which reduced the data base to 8 students in the experimental group and 9 students in the control group. For the check rides the rating booklets on 4 students were not completed which resulted in the following data return for each of the three check rides.

	Contact Check Rides		Instrument Check Rides
	Initial	Final	
Experimental Group (nominally 9 students)	8 students	9 students	8 students
Control Group (nominally 10 students)	9 students	10 students	9 students

(2) Incompletion of Special Form Items. Due to a variety of reasons outside of our control not all the flight items on the Special Forms were evaluated on each flight. Typical reasons for incompletion were:

- Student unprepared for maneuver. Maneuvers were introduced to the student at various points in the course; for instance the rectangular course maneuver was not introduced until the student had about 30 hours of flying.

- Weather. If, on a scheduled instructional flight, the flight had to be curtailed due to weather the Special Form maneuvers might be incomplete or omitted.

Flying Schedule Changes. Flight schedules were changed fairly frequently; for example, the student

might be directed to practice only certain maneuvers or a solo flight might be substituted for a dual flight. In these circumstances it was unavoidable that some omissions occurred in the completion of the special form.

The average completion over all progress rides of the Special Forms was 69.9% and for the check rides was 83.6%. (see also Appendix D).

The procedure which we have followed throughout this report is to report the data available. Hence, for different comparisons different numbers of students in the two groups appear. The individual data points were gained by summing over the groups the number of flight items passed and expressing this number as a percentage of the number of flight items which were evaluated.

In Figures 4 and 5 the continuous and dashed lines indicate the performance of the experimental and control groups respectively as measured by the Special Form.

The data in Figures 4 and 5 show that the two groups start out being essentially equal in both contact and instrument flight proficiency. In both cases there is some indication that later performance of the experimental group is superior to that of the control group. Analysis of variance of the data showed, however, no statistical difference between the two curves. Hence, it is concluded that these data (Figures 4 and 5) are suggestive at best.

The data in Figure 6 indicate that on the final check rides, for both contact and instrument flight, the experimental group completes a significantly higher percentage of maneuvers successfully as measured by t tests (see Appendix D, Table 9).

b) Other Criterion Measures

The three other criterion measures (regular school rating forms, time to solo, and Link trainer performance) all yielded entirely negative results. None of them indicated any difference between the experimental and control groups. Certain possible reasons why these negative conclusions may be discounted to some extent are provided in the discussion which follows in a later section.

c) Student and Instructor Opinion

After the end of the GVRT training period the experimental group of students filled out a questionnaire and were interviewed briefly. At this time there were 10 students remaining in the experimental group. Eleven instructors who had experimental group members as their students were interviewed also. Appendix E lists the questions asked and the replies made.

The 10 students were midly favorable to the GVRT. The general reaction of the students is represented by their response to the question, "If you were to take the course again would you prefer it with or without GVRT?" Six replied yes, and four, no. Some of the unfavorable responses contained criticisms which may be well founded; for instance, five students advocated the addition of foot pedals to simulate rudder control, one thought the movement of the dot on the oscilloscope should be reversed in order that the control/display relationship would be the same as in the aircraft. The latter and other suggestions for modification of the GVRT were with respect to its ability to teach perceptual interpretation of the instruments. The instructors also mentioned this point; for example, one instructor said, "...quickened my student's reactions and developed his ability to divide his attention in reference to aircraft attitude against flight instruments." However, the over-all instructor reaction may be classified most accurately as neutral or indifferent. In general, the instructors did not see the relevance of GVRT training to flying; their attitude was swayed also by the administrative problem that would arise of incorporating GVRT training into an already full program.

While some of the criticisms of the GVRT may be well founded, and accepting the fact that the instructors may have good intuitive feel for what is useful in flight training, it nevertheless appeared to the project team that the basic stumbling block to acceptance of the GVRT is its lack of face validity. Discrepancies between the GVRT and the aircraft were obvious to all and were mentioned often in a generally critical and somewhat puzzled way. The design philosophy of the GVRT contrasted strongly with the training philosophy most generally accepted, namely, that "the only way to learn to fly an airplane is to fly an airplane - preferably with a good instructor as your guide."

The prevalence of this attitude, quickly absorbed by students, makes it difficult to gain acceptance for generalized training devices. Certain modifications to the GVRT would serve to decrease negative transfer effects (real or imagined) and increase face validity.

2) Analysis of GVRT Data

The GVRT training program constituted a training treatment and the point of principal interest is the effects that GVRT training treatment had on various criterion measures. This has been discussed in the previous section. There are, however, two points of secondary interest.

a) Length of GVRT Training

The scores obtained on the Daily Test on the GVRT afford data to draw a learning curve. The average learning curve is shown in Figure 7. It indicates that performance levels off at about the 10th session (5 hours of direct practice). While this result indicates that a minimum of 5 hours of direct practice on the GVRT should be given, it does not necessarily indicate that more than 5 hours of practice should not be given nor that the students had reached their skill ceiling. Figure 8 shows the data gained from the pre-tests and major tests and indicates that improvement was continuing until the end of the GVRT training period. Our previous studies (3) had indicated that training up to 14 hours and possibly longer led to incremental refinement of control skills. Hence, it is concluded that at least 5 hours of direct practice on the GVRT should be given, and that further practice should be provided whenever possible.

b) Relationship of GVRT Scores and Pass/Fail the Course

While the number of individuals involved in this experiment does not allow for any correlational analysis for assessing whether the GVRT is capable of predicting whether an individual will pass or fail the course, it is considered that the following result is worthy of report.

The scores obtained by students in the experimental group on the GVRT daily tests given on the first three training days were summed and averaged for the group who eventally passed the course and for the group who failed the course for flying deficiency reasons. The group sizes were 9 students in the pass group and 5 in the fail group. Comparison of the mean GVRT scores for the two groups by t test yielded a t of 4.12 which is significant at $p < .01$. This result is interpreted as a provisional indication that the GVRT may have some capability as a selection instrument; further work is needed before any firmer conclusion can be drawn.

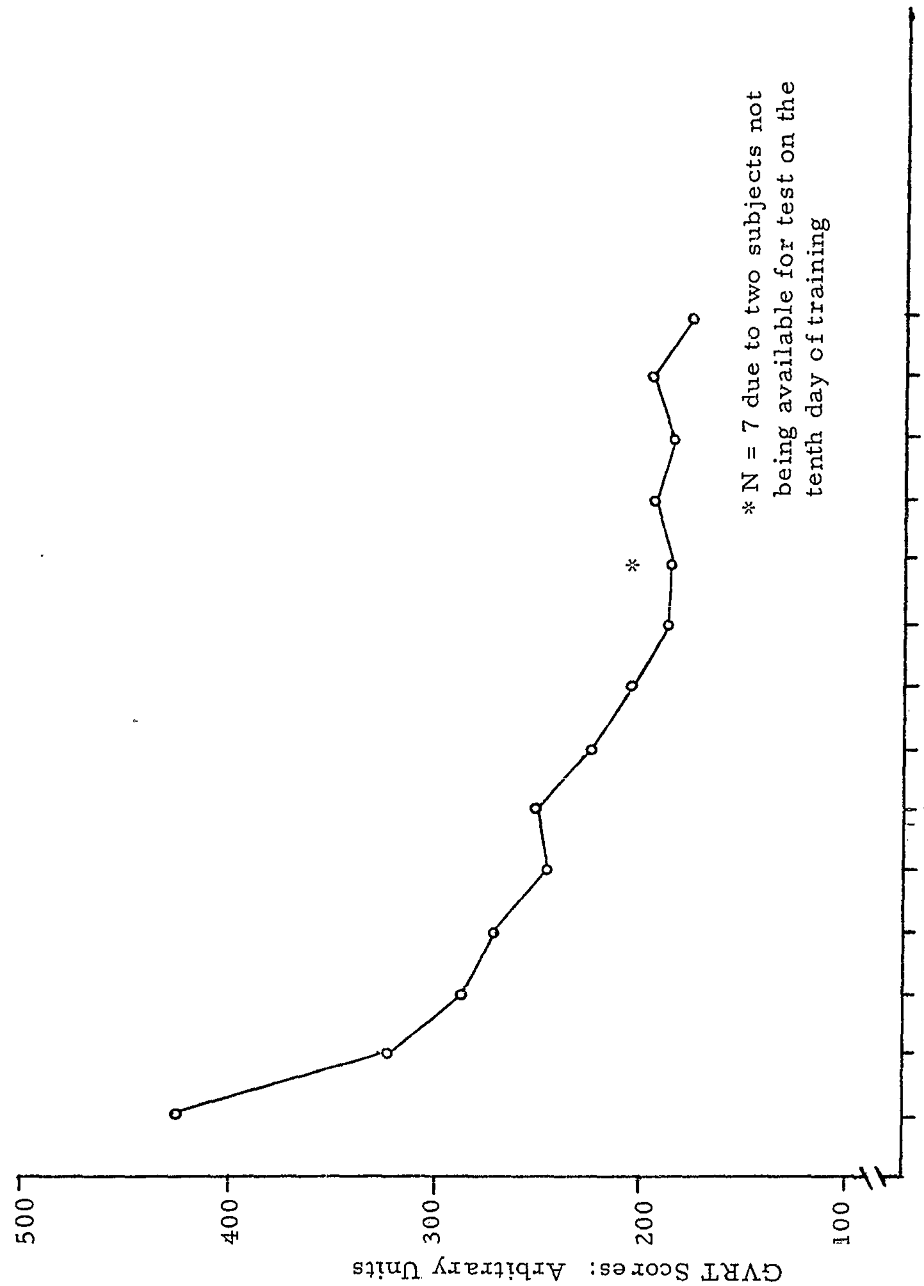

Figure 7. GVRT Tests: Experimental Group Mean Scores for Daily Test (based on the 9 students who passed the flying course)

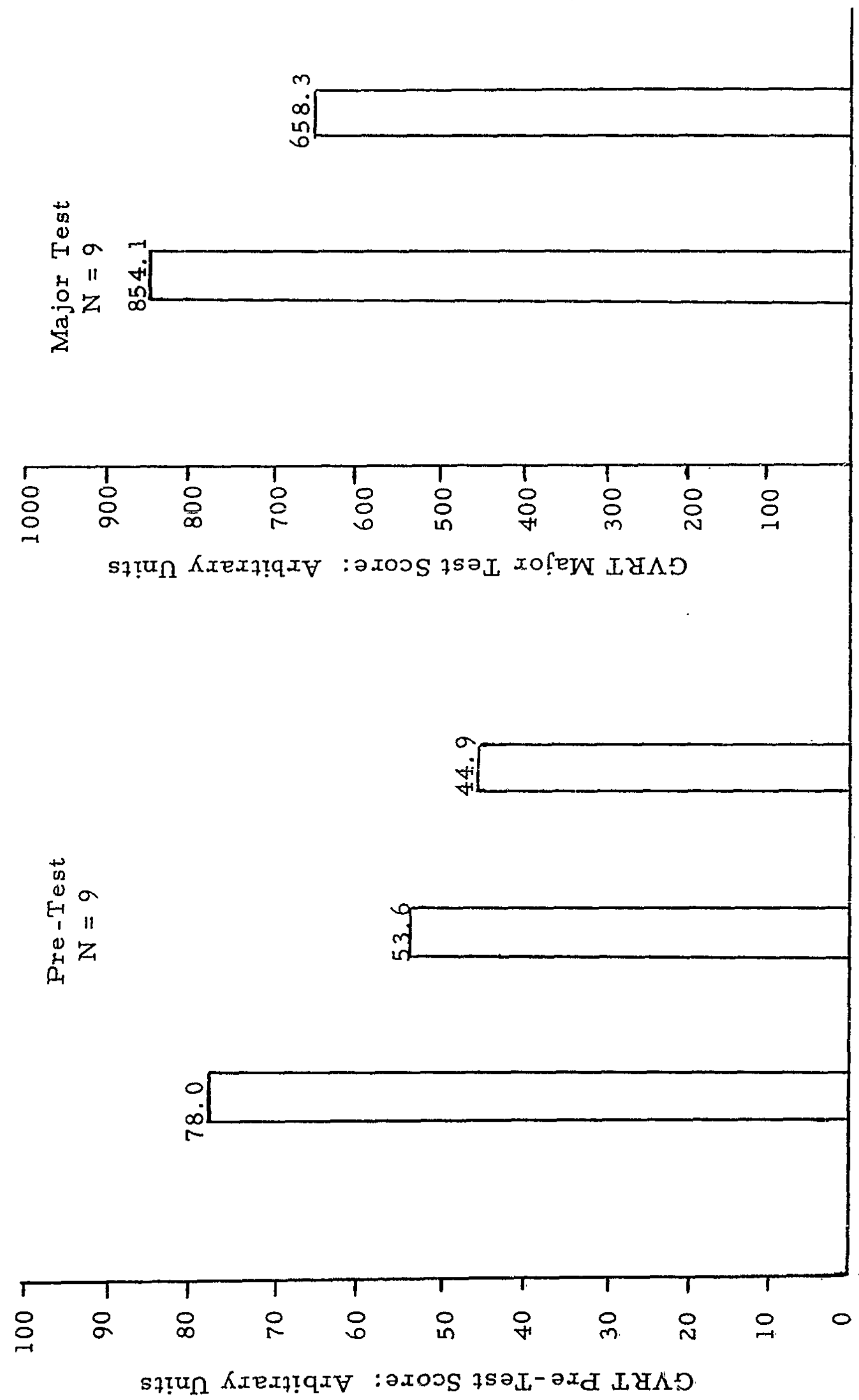

Figure 8. GVRT Tests: Experimental Group Mean Scores for Pre-Tests and Major Tests (based on the 9 Students who passed the flying course)

f. Discussion and Conclusion of Study 1

The results of this study provide relatively slight evidence for the training effectiveness of the GVRT.

The fact that the study had to be conducted on a non-interference basis incurred penalties in terms of incomplete data, which has already been referred to. The number of students who failed the course made an already small scale study even smaller. (The average expectation from past experience at the school, was that we would lose 4 students from each group for a total of 8; in fact, a total of 13 students were lost.) These facts make it less likely that if there existed real differences between the groups they could be demonstrated statistically.

A further consideration is the manner in which students were trained through the course. It appeared to the project team that the school had, as its mission, the requirement to produce pilots of a given proficiency - a "standard" pilot. Those students who did not appear to have the potential to make a pilot were eliminated, usually early in the course. Those that were retained and eventually passed the course did not receive equal training. It appeared that the weaker ones could receive up to 10 hours more training, spread through the course, than the stronger ones. From the point of view of the school's mission this differential treatment of students is appropriate, but clearly works to the disadvantage of an experimental program designed to improve some people more than others. The attempt to produce a "standard" pilot is reflected, in our opinion, by the absence of differences in the regular school ratings. According to these ratings the graduated pilots are very similar to one another and, as reported previously, there is no difference between the experimental and control groups on these ratings. The inference is that instructors see their task as one of bringing a man up to a standard and eliminating those who cannot make that standard.

The situation was, then, one in which it might be judged à priori difficult to prove that the GVRT afforded training benefits. The slender positive results obtained may be given, therefore, somewhat greater weight than might be ordinarily afforded them.

Some of the specific findings raise interesting issues. The finding that the experimental group was improved by about the same amount for both contact and instrument flying is compatible with the theory of a general skill component. Inasmuch as the GVRT

is specific, that is to say it is a singular device with certain invariant properties, it would be expected to benefit tasks involving instrument scanning more than other tasks. However, our premise has been that the GVRT would instill into trainees a general skill to perform in control loops, and that this skill once acquired, would be channelled, refined, and added to when the trainee was confronted with some specific task. What appears to have happened in this study is that the general skill transferred about equally to contact and instrument flight, and this finding is interpreted as supporting the theoretical position which underlies the concept of the GVRT.

The premise that what was transferred from the GVRT to the aircraft was a general skill also may be inferred from considering certain specific differences between the GVRT and the aircraft. As noted in the students' and instructors' comments, the GVRT was discrepant from the aircraft in two major ways: the absence of any foot pedals which are essential for control of the training aircraft and in the reversal of the control/display relationship. [1] If there existed specific negative transfer effects of any considerable nature from these major discrepancies between the training and real situations, it would be unlikely that the experimental group would have shown to such advantage. Of course, if the GVRT were modified to eradicate these or other discrepancies the experimental groups' advantage might have been greater than that found. However, it is not unreasonable to regard the facts as confirmatory of the theoretical position that the GVRT enables the transfer of a general skill component largely independent of specific components.

A practical point is raised by the findings. The data in Figure 6 indicate that use of the GVRT could enable a higher terminal proficiency to be achieved. However, it should be noted that proficiency in maneuvering an aircraft is only one, albeit

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[1] The position display on the GVRT is compensatory in character and can be said to be an "outside-in" display; when the spot is off center the stick must be moved in the opposite direction to null error. The attitude display on the aircraft (the near-equivalent to the GVRT Position Display) is pursuit in character and is said to be an "inside-out" display; when the aircraft is seen to move in relation to the artifical horizon the stick must be moved in the same direction in order to restore level flight.

important, component of a pilot's skill and that he has much else to learn. Probably the most practical way of incorporating the GVRT into flight training is to substitute GVRT training for some of the periods early in the course which are now scheduled for flight. This would relieve the pressure on aircraft availability and could result, for instance, in the same number of instructors being able to handle larger courses.

In conclusion, the first study has indicated provisionally that the GVRT improves student performance when added to a training course and has provided evidence which is compatible with the theory of a general skill component. It should be recognized that the results are not very powerful and indicate, perhaps more than anything else, that a more elaborate study should be undertaken.

4. Study 2: Submarine School Evaluation

a. General Plan

At the Submarine School there is a Skipjack submarine simulator.[1] It simulates the control station of Skipjack class submarines and is equipped with replicas of control panels and control sticks; the simulated control room physically pitches and rolls in accordance with the motions of the simulated ship.

The research plan had the following general form:

	Training Treatment	Criterion Tests
Experimental Group:	GVRT Training (A)	Skipjack (B)
Control Group:	Skipjack Training (B)	Skipjack (B)

The goal of the plan was to determine the degree to which the GVRT may be substituted for the Skipjack simulator in a training program.

The criterion tests were conducted on the Skipjack simulator for both groups. It would have been desirable to have had an ultimate criterion test, namely, performance in controlling a submarine under way; but this proved impossible to obtain.

[1] The Skipjack simulator is used in both the officer and enlisted men training courses. Its utilization is principally in the form of familiarizing men with the control station and it is not used on a regular basis to train men to achieve competency in handling a submarine.

b. Selection and Matching of Subjects

Subjects had to be selected for the experiment a few days before their three-week participation started; they were selected and run in the experiment four at a time. This administrative restraint made impossible the exact matching of groups. Matching was achieved as nearly as possible by selecting men who fell within the following restrictive categories:

- no previous ship guidance experience
- single men
- GCT (general abilities) - 55-65
- age - 18 to 22 years

It was considered that the men selected on this basis formed a fairly homogeneous group lying at about the average for enlisted men enrolled in the school.

c. Experimental Design and Subject Scheduling

The experimental group, consisting of 12 men, was trained on the GVRT and tested on Skipjack. The control group, consisting of 8 men was trained and tested on Skipjack. [1]

The experimental group was split into two equal sub-groups. Sub-group A's schedule of training and testing was made as closely as possible equivalent to the schedule for the control group; sub-group B received extra GVRT training in order to investigate whether this extra training would improve performance on Skipjack.

Inspection of Table 3 shows that experimental sub-group A and the control group received 45 minutes of practice per day, and experimental sub-group B received 1 hour of practice per day. Included in each day's practice session was a "Daily Test" consisting of 10 standard problems and taking about 15 minutes to conduct. These "Daily Tests" were regarded as integral

[1] It would have been desirable, but was not feasible, to have had more subjects per group, to equalize the numbers in the groups, and to have provided more training time.

Table 3

Summary Schedule of Subjects Training and Testing:
Study 2

	Experimental Sub-Group A 6 Subjects	Experimental Sub-Group B 6 Subjects	Control Group 8 Subjects
Basic Unit Period of Training	45 minutes per day	60 minutes per day	45 minutes per day
Number of Days in "Training" Status	8 days	8 days	9 days
Total hours "Training" Status	6 hours	8 hours	6-3/4 hours
1st Day Familiarization and Pre-Test	Familiarization GVRT 1/2 hour Skipjack 1/2 hour: Pre-Test GVRT 1/4 hour Skipjack 1/4 hour	Familiarization GVRT 1/2 hour Skipjack 1/2 hour Pre-Test GVRT 1/4 hour Skipjack 1/4 hour	Familiarization Skipjack 1/2 hr. Pre-Test Skipjack 1/4 hr.

Table 3 (Con't.)

Training	On days 2, 3, 4, 5, 6, 8, 9, 10 (Each Training Period Included a 15 Minute Daily Test)	On days 2, 3, 4, 5, 6, 8, 9, 10	On days 2, 3, 4, 5, 6, 8, 9, 10, 11
Testing	On days 7 and 11 Pre-Tests and Major Tests GVRT 3/4 hour Skipjack 3/4 hour (On day 11 Skipjack Tests Given Before GVRT Tests)	On days 7 and 11 Pre-Tests and Major Tests GVRT 3/4 hour Skipjack 3/4 hour	On days 7 and 12 Pre-Tests and Major Tests Skipjack 3/4 hr.
TOTALS			
1st Day	1-1/2 hours	1-1/2 hours	3/4 hour
2nd Day through Final Skipjack Test	8-1/4 hours	10-1/4 hours	8-1/4 hours

with the practice period and as a component of the training experience, and hence the subjects were considered to be in training status for the period of the Daily Test.

On the first day of the schedule each subject was familiarized with the training devices and given a short Pre-Test. The Pre-Test consisted of 5 simple problems. The experimental subjects received familiarization and Pre-Test on both the GVRT and the Skipjack, while the control group subjects received familiarization and Pre-Test on the Skipjack only. The familiarization consisted of the minimum possible explanation of the training devices so that the subjects could comprehend the nature of the devices and the broad meaning of the instruments. The familiarization procedure was undertaken so that the subjects could undertake the first Pre-Test in something more than a haphazard manner.

On days 7 and 11 (12 for the control group) the Major Test was given. The Major Test consisted of 20 problems and included problems which required considerable skill to control. Preceding the giving of the major test, each subject was retested on the Pre-Test. The experimental group undertook these tests on both the GVRT and Skipjack, while the control group undertook the tests only on Skipjack. Due to the extra time at controlling a device afforded to the experimental group by reasons of taking the major tests on both devices, one extra day of training was given to the control group in order to equalize the total time of exposure to a training device of the control group and experimental sub-group A.

It should be noted that the familiarization and first Pre-Test period (1st day) was less for the control group than for the experimental group due to the control group working only with the Skipjack. It was considered that this time should not be compensated for by providing a further day of training on the Skipjack due to the different quality of the experience between the first familiarization period and later training periods. On the final day of testing the experimental subjects received the Skipjack tests first, and the totals in Table 3 are the total hours down to this point. The experimental subjects went on to take the GVRT tests.

In addition to the above schedule as many subjects as possible were retrieved after they had completed their 8-week course which included some limited amount of training on various simulators and some ship experience in some cases, and were tested again on Skipjack (pre-test and major test). Seven experimental subjects and 4 control subjects were re-tested.

The practice and training periods referred to are "direct" practice and are defined, as in the Flight School program, as the time spent actually controlling the devices. As in the Flight School program, subjects were run in pairs, one observing while the other worked. Pre-Test, Progressive Parts Training, Variable Training, and Major Tests on the GVRT were essentially the same as described for the Flight School schedule. The schedule with respect to Skipjack training and testing resembled as closely as possible the schedule for GVRT training and testing. Differences inevitably occurred due to the impossibility of giving variable training on the Skipjack since it is a simulator with fixed characteristics. The only dynamic freedom available was the speed of the simulated ship and this was varied during the training and testing on Skipjack. In addition, the initial conditions defining the state of the ship at the start of the problem were varied.

d. Criterion Measurement

Skipjack performance was scored by entering the analog computers subserving the dynamic simulation and picking off the voltages proportional to error in relative depth and relative course. These error voltages were combined and integrated to provide a single error score (Appendix G). In addition student opinions were obtained.

The task of the subject on the Skipjack trainer was to null errors in relative depth and relative course and hence was essentially the same as the GVRT task. [1]

e. Results and Analysis

1) Analysis of Experimental and Control Group Data on Criterion

The over-all results of the evaluation are contained in Table 4. All scores are in arbitrary units of integrated error.

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[1] The difference between the Skipjack and GVRT tasks was that in Skipjack relative course error had to be nulled, and in the GVRT relative lateral position error had to be nulled. Position error is the integral of course error and, therefore, the Skipjack task was "easier" by one integration step than the GVRT task.

Table 4. Average Skipjack Error Scores
(Arbitrary Units)

Pre-Test	Start	Middle	End	Re-Test
Experimental Sub-Group A (6 subjects)	29.8	26.0	24.7	21.7 N = 7
Experimental Sub-Group B (6 subjects)	27.0	26.3	24.4	
Control Group (8 subjects)	27.8	22.3	20.6	18.3 N = 4
Major Test				
Experimental Sub-Group A		125.5	106.0	104.7 N = 7
Experimental Sub-Group B		129.0	113.1	
Control Group		103.0	93.1	87.6 N = 4

First it should be noted that there are no differences between experimental sub-groups A and B on the Skipjack Major Test scores. None of the possible comparisons between the two experimental groups showed differences between them (see Appendix H). The similarity of the two groups was checked also by inspecting the learning curves of the two groups obtained on the GVRT Daily Tests undertaken in the practice sessions; these curves also showed no difference (see Appendix H). Hence, the two experimental sub-groups were treated in the following analysis as one group.

At the start (1st day) it was found that the experimental and control groups were not different in terms of the pre-test.

Every comparison thereafter showed the control group significantly superior to the experimental group, with the exception of the re-test scores on the pre-test.

The groups may be compared in terms of the degree of transfer of training achieved by the experimental group relative to the control group. For this purpose, the following equation from Woodworth and Schlosberg (21) was used.

$$\%\text{ transfer effect} = \frac{\text{Final E score} - \text{Initial C score}}{\text{Final C score} - \text{Initial C score}} \times 100$$

where E score is experimental group mean
C score is control group mean

Application of this formula to the initial and final pre-test scores, which are the only ones which provide an initial comparison, yields the following results:

$$\%\text{ transfer effect} = \frac{24.5 - 27.8}{20.6 - 27.8} \times 100 = \frac{3.3}{7.2} \times 100 = 45.8\%$$

This computation indicates that the amount by which the experimental group changes in arbitrary units is 45.8% of the amount by which the control group improves with respect to the initial score of the control group.

2) Student Opinion

Ten of the twelve students of the experimental group filled out questionnaires and were interviewed at the completion of their three week participation. Three of the questions and answers were:

Question	Favorable	Non-Favorable
Do you feel that your training on the GVRT helped you to control the Skipjack Simulator?	9	1
Question		
Do you think the GVRT was effective in teaching you eye-hand coordination skills necessary for the control of Skipjack?	10	0

Question	Favorable	Non-Favorable
Did you enjoy training on the GVRT?	10	0

Other questions and the details of the subject's answers are listed in Appendix I. Many of the qualitative answers centered around the beneficial training received in terms of instrument scanning, judgment, anticipation, timing of control actions, and ability to control high speed problems.

Some students noted the difficulty they had in scanning, interpreting and acting on the indications displayed on the Skipjack instrument panel. The project team had the definite impression that the major difficulty in transferring from the GVRT to the Skipjack simulator was due to the differences in instrument design and layout.

f. Discussion and Conclusions of Study 2

This study indicates that the GVRT is only a partial substitute for specific training devices. The control group, trained and tested on the Skipjack simulator, was superior on all counts to the experimental group trained on the GVRT. However, there was a 45.8% positive transfer of training from the GVRT to the Skipjack. The students' opinion and their reports of their experience during their regular training course show the GVRT in a favorable light.

While the evidence does not allow for any unique interpretation, it is compatible with the theory advanced concerning the GVRT. It may be hypothesized that the positive transfer achieved was due to the inculcation of a general skill, and the incompleteness of the transfer was due to the discrepancies in certain specifics between the two task situations.

It may be mentioned in this connection that the senior author, relatively well experienced in controlling vehicles (and certainly in controlling the GVRT), found the instrument layout on the Skipjack difficult to use; it took him a long time to develop any real skill at the task. He feels that the perceptual difficulties of the task are unusually onerous and reflect the absence of human engineering in the panel design.

However, inasmuch as the Skipjack vehicle and its control station may be representative of existing vehicles, it is clear that the GVRT is not a complete answer to the training problem.

C. Modification of General Vehicular Research Tool

1. General

In the course of the field studies, the need for certain modifications to the GVRT became apparent. The modifications mentioned below are, in some cases, moves to render the GVRT more like some specific real system. It is considered, however, that the utility of the GVRT lies in its generality and simplicity. Modifications which would enable greater specific simulation would increase its cost and make it more complex. Hence, such modifications should be carefully considered and kept to a minimum, otherwise the GVRT will have lost its major advantage.

2. Labels

Provide slots over each instrument on student's console which refer to control or vehicle motions. Prepared tabs would be put in these slots, with words upon them which would be appropriate for the particular vehicle used at the school in question.

3. Position Display (Oscilloscope)

Provide a switch so that this display can be changed between an outside-in display (as at present) and an inside-out display. This will enable proper simulation of control-display relationships and stop the negative transfer effects deriving from reversals in control-display relationship (as at Flight School). Consideration should be given to changing the display characteristics when an inside-out display is selected. An inside-out display is necessarily "pursuit" in nature and is best represented by a moving target (driven by a function generator) which the operator pursues with a moving symbol.

4. Lateral or Vertical Dimension Selection Switch

Provide a three- position switch to select lateral, vertical, or combined dimensions of control. Experience indicated that practice in one dimension only is desirable in the early part of training.

5. Scoring

It is recommended that the separate lateral and vertical scoring instruments be eliminated. Experience indicated that these did not provide any useful additional feedback information over the combined score instrument. Should modification No. 4 above be implemented, the combined score instrument would read a single dimension score when a single dimension is selected.

6. Manual Throttle

It is recommended that the manual throttle be modified. It appeared that little useful training was accomplished by use of the manual throttle in the studies reported in this report. Furthermore, the present circuits allowed a form of cheating when using manual throttle. The simulated vehicle could be brought toward the center null point at high speed; when near the center the speed could be cut to a minimum thereby diminishing greatly the rate at which the dot could possibly move away from center. Circuits could be devised to minimize the payoff from this form of control action.

Elimination of the manual throttle is not positively recommended at this time because it is thought that in certain circumstances practice in controlling a throttle is desirable. Further evaluation is needed before determining the answer to this question.

7. Turbulence

Modification to the character of the forcing functions would be beneficial. The present forcing functions cover too wide a range; the "slow small" condition provides insufficient displacement, and the "fast large" condition provides too much displacement. In addition a more versatile function generator than the one presently employed, enabling the introduction of many types of forcing functions, would be beneficial.

8. Hood over Screen

It is recommended that the oscilloscope screen have a hood placed over the top of the oscilloscope to prevent reflection of ceiling lights, etc. However, free view of the screen must not be impaired.

9. Hand Pad

It is recommended that a soft hand pad be placed immediately in front of the control stick.

The following two modifications are major in nature. At this time it is recommended that they be considered but not incorporated without proper evaluation.

10. Special Displays and Controls

In order to increase the face validity and acceptability of the GVRT at various training schools, as well as to increase its effectiveness, it is suggested that different sets of displays and controls be made up. Each set would be suitable for different training establishments; one each, say, for aircraft, submarines, and drone schools. The particular controls and displays in each set would have properties which are similar to the controls and displays of the real situation. For example, the aircraft set might contain foot controls and an artificial horizon instrument.

11. Adjustive Circuits

Adjustive circuits for use in training devices are being developed currently (11, 14). The adjustive concept is that the score that a man obtains on previous trials sets the level of difficulty of the present trial. In this manner the difficulty of the problem always keeps pace with the level of skill of a student.

It is considered that incorporation of such an adjustive feature would be of real benefit to the GVRT. While it would provide primarily an optimum training schedule for each individual student (each student goes at his own pace similarly to the teaching procedures used with teaching machines), it would provide a side benefit in that the device would need very little of the time of an instructor.

The development of the most useful form of adjustive circuit requires study, for self-adjustment can be done in many ways, not all of which would maintain the full benefits of the GVRT as used in this study. A small scale research and development study is needed to investigate the optimal incorporation of adjustive circuits into the GVRT.

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IV. APPENDICES

APPENDIX A

Student Attrition Rate Against Biographical Characteristics at Flight School

Through the courtesy of Dr. Arthur C. Poe, Jr., Education Advisor, Ft. Rucker, Alabama, we were provided with the following data. These data served as background material when the selection and matching procedures for the experimental and control groups were carried out.

Table 5. Attrition Rates of a Sample of 745 Students at Primary Fixed Wing Flight School (Sample drawn from 1960-61 intake at school.)

Description	Entered	Eliminated	% Eliminated
Amount of Education			
College degree	490	112	22.8
Some college	130	33	25.3
High school only	119	27	22.6
Military Component			
Regular Army	286	60	20.9
Reserve	324	77	23.7
National Guard	133	39	29.3
Rank			
Second Lt.	469	99	21.1
First Lt.	237	71	29.9
Captain	9	1	11.1
Field Grade	29	5	17.2
Age			
20	3	1	33.3
21	20	3	15.0
22	112	18	16.0
23	166	30	18.0
24	108	31	28.7

Description	Entered	Eliminated	% Eliminated
25	93	25	26.8
26	55	14	25.4
27	43	16	37.2
28	42	14	33.3
29	44	15	34.0
30	23	8	34.7
31	7	4	57.1
32	4	0	
33	2	0	
34	3	0	
36	1	0	
37	4	2	
38	4	0	
39	5	0	
40	3	1	
41	3	1	
42	2	0	
43	2	0	
44	3	1	
Married	530	112	21.1
Second Lt.	306	60	19.6
First Lt.	183	48	26.2
Captain	9	1	11.1
Field Grade	29	5	17.2
Single	215	64	29.7
Second Lt.	161	39	24.2
First Lt.	51	23	45.0
No Captains or Field Grade			

APPENDIX B
Training and Testing Schedules for Study 1

The schedule for the experimental group is laid out in Table 6. This table sets out a nominal schedule which represents the average occurrence of events. Interruptions due to weather, equipment malfunctions, unavailability of subjects, etc., caused some variation from the schedule for any one individual.

The GVRT schedule was conducted by taking pairs of subjects at each session. Each session lasted one hour. While one subject operated the GVRT the other subject observed. The subjects changed roles every 5 to 10 minutes. The observer subject was not passive; he was encouraged to talk about the problems, and to analyze his own and his colleague's performance. Each pair of subjects generally involved themselves in friendly competition by seeing who could obtain the best score on a certain problem.

The GVRT training program started with a session devoted to orientation towards the experiment [1], familiarization with the equipment, a short practice session consisting of easy problems, and a Pre-Test. The Pre-Test consisted of five simple problems and was designed to discover any considerable differences between subjects in initial ability. Each pre-test problem lasted 15 seconds and involved "simple" dynamics with no turbulence. The same pre-test was repeated at the times when the Major Test was given to determine the learning curve for simple problems.

The second session consisted primarily of Progressive Parts Training. Progressive Parts Training consists of training the subject first on the indicators which are most directly connected to stick motion (control elements, e. g., planes and rudder), and thence progressively to the indicators showing successive integrations of stick motion (e. g., for the vertical dimension, angle rate, angle and relative altitude). At each integration step, the subject had to demonstrate adequate control before proceeding to the next integration step.

1 The entire class of students had received an introductory lecture in which the general purpose and proposed conduct of the experiment had been explained.

Table 6
Schedule for Experimental Group

FLYING SCHEDULE SPECIAL FORM EVALUATION						GVRT TESTING & TRAINING SCHEDULE				
	Flying Hours	PROGRESS RIDES		CHECK RIDES			TESTS			
Week of Training	End of Week	Contact	Inst.	Contact	Inst.	Session No.	Pre	Major	Daily	TRAINING
1	1 1/4					1	X		X	Orientation, Familiarization, Practice
		2	Hours of Instrument Flight			2			X	Progressive Parts
2	5 1/2	5				3			X	Training and Practice
						4			X	Variable Training
3	10 3/4	9				5			X	Variable Training
		13				6			X	Variable Training
4	18	18				7			X	Variable Training
						8			X	Variable Training
5	24					9	X	X	X	Variable Training
						10			X	Variable Training
6	31	27				11			X	Variable Training
						12			X	Variable Training
7	38 1/2	35				13			X	Variable Training
				41		14			X	Variable Training
8	46			(#1)		15			X	Variable Training
						16			X	Variable Training
9	54	48	3			17	X	X	X	Variable Training
10	61 1/2		8							

Note: Each GVRT session lasted for one hour approximately.

Table 6 (Continued)
Schedule for Experimental Group

FLYING SCHEDULE
SPECIAL FORM EVALUATION

Week of Training	Flying Hours End of Week	PROGRESS RIDES Contact	PROGRESS RIDES Inst.	CHECK RIDES Contact	CHECK RIDES Inst.
11	71	66			Hours of Instrument Flight
12	78	78	13		
13	86				
14	93		19		
15	98 1/2	94			
16	107 1/2				20
17	115	110			
18	120			120 (#2)	

After working at some practice problems, the subjects undertook the Daily Test. The Daily Test consisted of 10 problems covering a wide range of dynamics; the problems were 15, 30, or 60 seconds long. The Daily Test consisting of the same 10 problems was given at the end of each session to each subject throughout the entire GVRT training period.

A third session was conducted identically to the second session.

The fourth session started the Variable Training Program which was continued until the end of the training period. Variable Training consists of varying the dynamics of practice problems, particularly stability characteristics, across the range of dynamics possible on the GVRT. The policy pursued was that the range of dynamics presented in practice should remain about constant, but as skill increased the majority of problems should increase in difficulty. The shift in difficulty was correlated, according to the experimenter's best judgment, with the increase in skill of the subject. At or about the 12th session manual control of the throttle was introduced, and about 5% to 10% of practice thereafter was conducted with manual throttle control.

The experimenter's primary role in Variable Training was to program the GVRT; in addition and particularly in the first few sessions, he gave instruction and analyzed faults in performance. He avoided any predominating or authoritative role. He attempted to guide initial performance into good skill patterns and later allowed the subject to teach himself by observing his own and his colleague's performance. However, the experimenter allowed himself discretion to program problems and to repeat problems according to the progress of the subject and the particular control problems he encountered[1].

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1 It is noted that these procedures are conceptually similar to automatic adjustive programming. From our previous studies we had noticed the apparent effectiveness of adjusting problem difficulty to correlate with subject skill development. Subsequently, one of the authors had developed automatic circuits to adjust problem difficulty as a function of score obtained (14). The procedures outlined in the text were an effort to implement the adjustive concept, using the experimenter as the adjustive loop, while abiding by the principle of variable training.

A Major Test on the GVRT was given twice, halfway through and at the end of training. It consisted of twenty problems, ranging from slow stable problems (submarine like) to fast unstable problems (helicopter like); the majority of problems had dynamics similar to aircraft dynamics; the problems were 15, 30 or 60 seconds long. A complete description of all the GVRT configurations used in the training periods and for the tests is on file at U. S. Naval Training Device Center and may be obtained upon request.

APPENDIX C
The "Special Forms" Used for Study 1

The special forms occurred in two versions for contact and instrument flight. For "progress ride" evaluations the forms were filled in by the student's instructor during the course of instructional flights. For "checkride" evaluation the forms were filled in by the check pilot in the course of check rides.

The pilots undertaking the ratings were requested to fly the student pilot on each of the listed maneuvers during each scheduled flight. As explained in the text some omissions occurred. In every instance, except one, the forms could be filled in by objective means, i. e., by regarding the instrument panel. The exception is the case of the item "planning on turns" while undertaking rectangular course patterns. This was included because:

1. Instructors considered that proper planning (i. e., starting the turn correctly in order to come out of the turn at the proper position) was the core of the problem.

2. Instructors agreed unanimously, and we concurred, that it was easy to discriminate good and bad planning.

Referring to the forms, shown in Figure 9, it is seen that the instructor was provided with a box opposite each designated item of each maneuver; he either checked the box (for correct performance), crossed it (for incorrect performance), or shaded it in (for omission).

The booklets containing the forms were accompanied by instructions and contained places for noting the date, and the student and instructor's name. In the case of the progress rides additional notation was provided for all turn maneuvers so that the pilot would fly left and right turns alternately and an equal number of times.

Figure 9
Special Forms

CONTACT FLIGHT

1) Climbing Turn & Level Off, 90°

A/S 80 mph (± 5 mph) ( )

Bank 20° (± 5°) ( )

Heading (± 5°) ( )

Altitude (± 50') ( )

2) Straight and Level (1 min.)

Altitude (± 50') ( )

Heading (± 5°) ( )

3) Level Turns

a. 90°

Altitude (± 50') ( )

Bank 37° (± 5°) ( )

Heading (± 5°) ( )

b. 360°

Altitude (± 50') ( )

Bank 60° (± 5°) ( )

Heading (± 5°) ( )

4) Slow Flight

a. Straight & Level (30 sec.)

Altitude (± 50') ( )

Heading (± 5°) ( )

b. Level Turn 30° Flaps, 90°

Altitude (± 50') ( )

Bank ( )

Heading (± 5°) ( )

5) Descending Turn & Level Off, 90°

A/S 80 mph (± 5 mph) ( )

Bank 30° (± 5°) ( )

Heading (± 5°) ( )

Altitude (± 50') ( )

6) Rectangular Course

a. At Normal Cruise

Altitude 500' (± 50') ( )

Ground Track on Legs
1000' (± 200') ( )

Planning on Turns ( )

Figure 9 (Continued)
Special Forms

CONTACT FLIGHT

b. <u>At 70 mph & 30° Flaps</u>

Altitude 500' (± 50')	( )
Ground Track on Legs 1000' (± 200')	( )
Planning on Turns	( )
A/S 70 mph (± 5 mph)	( )

Figure 9
Special Forms

INSTRUMENT FLIGHT

1) Straight & Level

a. At Normal Cruise (1 min.)

Altitude (± 50') ( )

Heading (± 5°) ( )

b. While Changing Airspeed

Altitude (± 50') ( )

Heading (± 5°) ( )

c. At Slow Cruise (1 min.)

Altitude (± 50') ( )

Heading (± 5°) ( )

A/S 100 mph (± 5 mph) ( )

2) Straight Climb & Level Off for 500'

Heading (± 5°) ( )

A/S 100 mph (± 5 mph) ( )

Altitude (± 50') ( )

3) Climbing Turn & Level Off, 90°

A/S 100 mph (± 5 mph) ( )

Bank 15° (± 5°) ( )

Heading (± 5°) ( )

Altitude (± 50') ( )

4) Level Turns

a. 90°

Altitude (± 50') ( )

Bank 15° (± 5°) ( )

Heading (± 5°) ( )

b. 360°

Altitude (± 50') ( )

Turn Rate ( )

Heading (± 5°) ( )

5) Straight Descent & Level Off for 500'

Heading (± 5°) ( )

A/S 100 mph (± 5 mph) ( )

Altitude (± 50') ( )

6) Descending Turn & Level Off, 90°

A/S 100 mph (± 5 mph) ( )

Bank 15° (± 5°) ( )

Heading (± 5°) ( )

Altitude (± 50') ( )

APPENDIX D

Statistical Summary of Study 1

1. Special Form Data: Progress Rides

All data are derived only from those students who passed the course. Table 7 shows the average number of flight maneuvers scored for each group on each progress ride.

Table 7

Average Number of Maneuvers Scored:Study 1
(Out of possible 28 per evaluation occasion)

Contact Flight

Hours of Training (Nominal)	Exp. Group	Control Group
2	13.5	14.0
5	17.0	15.2
9	16.6	18.7
13	15.4	13.6
18	12.9	13.7
27	22.9	20.9
35	19.5	17.8
48	22.1	20.3
66	25.6	21.3
78	25.3	23.8
94	16.8	13.9
100	15.6	17.0

Instrument Flight
(Out of a possible 27 per evaluation occasion)

Hours of Training (Nominal)	Exp. Group	Control Group
2	16.5	17.9
5	23.0	26.7
8	26.3	26.7
12	23.6	26.9

Entries in Table 8 are percent of maneuvers accomplished within criterion of those attempted. Data in Tables 7 and 8 are based on 8 subjects in the experimental group and 9 subjects in the control group. The progress ride data therefore is missing information on two subjects, one from each group. The two booklets in question were not recovered from the instructional staff of the school.

Table 8

Special Form Data: Average Percent Flying Performance on Progress Rides

Contact Flight

Hours of Training (nominal)	Exp. Group	Control Group
2	23.1	18.3
5	30.9	24.8
9	48.9	48.2
13	70.7	51.6
18	56.3	72.4
27	66.1	64.9
35	75.0	76.9
48	76.8	74.9
66	89.8	74.5
78	90.6	84.6
94	88.8	86.4
110	88.0	88.2

Instrument Flight

Hours of Training (nominal)	Exp. Group	Control Group
2	27.0	46.6
5	69.6	68.7
8	89.5	85.4
12	84.7	84.7

2. Special Form Data: Check Rides

Table 9 provides the data gained from the final check rides.

Table 9

Special Form Data: Percent Flying Performance on Final Check Rides

Final Contact Check Ride

	Maneuvers			
	Total	Correct	% Correct	σ %
Experimental Group (N=9)	201	188	93.5	1.74
Control Group (N = 10)	218	180	82.6	2.56

t test between percentage correct = 3.52, $p < .01$

Final Instrument Check Ride

	Maneuvers			
	Total	Correct	% Correct	σ %
Experimental Group (N=8)	213	191	89.7	2.10
Control Group (N = 9)	243	195	80.2	2.55

t test between percentage correct = 2.88, $p < .01$

APPENDIX E

Student and Instructor Opinion: Study 1

Seven questions were answered by the ten students of the experimental group upon completion of their GVRT training period. The questions were first asked in questionnaire form and the students wrote their replies. Each student was subsequently interviewed, and the attempt was made to verify his replies by questioning and discussion. The questions and replies were as follows:

1. How has the GVRT affected your learning to fly? There were 5 positive, 3 neutral, and 2 negative replies to the question.

   a. Positive replies included such comments as:

      . Training on the GVRT facilitated development of a good scanning or cross-check procedure for instrument flying, i. e., division of attention. (5 students)

      . The GVRT helped in "anticipating the outcome of a maneuver." (1 student)

      . GVRT training improved reaction time. (1 student)

      . Improved alertness. (1 student)

   b. Neutral replies stated that there was no effect on contact flying.

   c. Negative replies were:

      . Use of CRT display on the GVRT caused some negative transfer in regard to the use of the attitude indicator in the aircraft. (1 student)

      . The GVRT training schedule in the pre-solo phase imposed some rather stringent time requirements on pilots so that some thought their work load was somewhat heavy. (2 students)

2. In summary, has the GVRT training helped, made no difference, hindered? There were 3 positive replies, 4 neutral, and 2 negative replies.

3. If you were to take the course over again would you prefer to have it with or without the GVRT? There were 6 positive replies and 4 negative replies.

4. Did you enjoy working with the GVRT? There were 10 positive replies.

5. Name the aspects of flying most affected by practice on the GVRT.

   a. Positive replies included:

      - Coordination and anticipation of corrective stick movements. (3 students)
      - Planning and jusgment. (1 student)
      - "Retention." (1 student)
      - "Division of attention." (1 student)
      - "Reaction time." (1 student)
      - Reaction to insensitivity and stick lag encountered during taxiing procedures. (1 student)

One student thought that GVRT training had no effect on contact flying. One student believed that there might have been some hindrance with contact and instrument flying because of the lack of rudder pedals on the GVRT and the negative transfer from the scope on the GVRT to the attitude indicator on the aircraft. [1]

6. Do you have any suggestions for improving the design or use of the GVRT? Five students answered no. Other replies included:

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[1] Same student as in 1c.

- Greater simulation of controls on the GVRT to those of the aircraft. (5 students)

- Addition of rudder pedals. (3 students)

- Increase the size of GVRT control stick to that of the aircraft. (2 students)

- Pressures on GVRT control stick should be more similar to those experienced on the stick of the aircraft. (1 student)

- A soft pad should cover the corner in front of the control stick and the CRT should be larger and hooded to prevent any reflection of nearby light sources. (1 student)

7. Do you think that this has been a fair test of the GVRT? If no, why not? There were 2 affirmative replies and 3 "no comments."

   a. Reasons for 5 negative replies were:

      - "Sample size too small." (1 student)

      - The differences in instructor flying techniques and grading methods were too great. (2 students)

      - The GVRT would have received a fairer test if the training schedule hadn't been a hit or miss affair after the pre-solo phase due to the encountered weather problems and resulting overloaded flying schedule. (1 student)

      - There was a large dissimilarity in the controls between GVRT and A/C. (1 student)

      - Should have been more regularly scheduled training periods and more practice time. (1 student)

Eleven instructors were interviewed at the completion of the GVRT training period. They were asked the following four questions:

1. Has the GVRT helped, made no difference, hindered in regard to your student's flying performance? Please explain. Two instructors said the GVRT "helped," 7 said it "made no difference," and 2 instructors didn't make any reply. There were no negative replies.

   a. Positive replies were:

      - "My student soloed first in my group of three."

      - GVRT training....... "quickened my student's reactions and developed his ability to divide his attention in reference to aircraft attitude against flight instruments. I am sure it has not hindered his progress."

   b. Neutral replies were:

      - "My student had a low aptitude for flying."

      - Unable to detect more than normal development. (2 instructors)

      - It appears that the GVRT would have helped during the instrument phase of flying,[1] because it would have probably helped the student obtain a good cross check that is needed for instrument flying.

      - "No noticeable difference."

      - My student "had no more difficulty than any other average student. At times he would use the aileron too much."

      - My student "has been slow in the A-1 phase (first 9 weeks) mainly caused by poor directional control in the solo phase."

2. What is your general reaction to the GVRT training program?

      - "The GVRT schedule was pliable enough not to interfere greatly. It was very little trouble."

[1]At the time the GVRT training ceased and the instructors and students were interviewed, the students had performed little or no instrument flying. Some Link training had been given.

- There was a conflict in scheduling the GVRT during flight time. (2 instructors)
- If used, the GVRT should be scheduled during academic time.
- "If we had to schedule it and Link it would be too much."
- "The GVRT training program wasn't related in any way to aircraft feel or reaction. I feel this type training is of no help in teaching primary fixed wing training.

3. Have you any suggestions for improving the design of the GVRT?

    - Install rudder pedals to provide for eye-hand-foot coordination. (5 instructors)
    - "Install more instruments to develop their (students') cross check."
    - "Try to design the machine so a student can relate the problems given in the GVRT to flying an aircraft."
    - No suggestions. (6 instructors)

4. Have you anything to suggest to aid us in interpreting the results?

    - "GVRT developed a good cross check procedure for instrument flying." (2 instructors)
    - "Don't think the GVRT can be fairly evaluated with this course due to high attrition rate."
    - "The choice of aircraft for this experiment was poor, due to the fact that rudder coordination is crucial to the control of the L-19 on the ground and in the air. In many aircraft rudder pedals are used only on take-offs and landings for braking and directional control. Once in the air rudder pedals are hardly if ever used." (1 instructor)
    - No answer. (7 instructors)

APPENDIX F

Training and Testing Schedule for Study 2

Table 10. Detailed Schedule for Experimental and Control Groups for Study 2

Training Day	EXPERIMENTAL GROUP: PROGRAM FOR EXPERIMENTAL TIME PERIODS (HOURS) (A=6 Subjects, B=6 Subjects)	Hours A	Hours B	CONTROL GROUP: PROGRAM FOR CONTROL GROUP TIME PERIODS (HOURS) (8 Subjects)	Hours
1	GVRT Familiarization and Practice	.5	.5	Skipjack Familiarization and Practice	.5
	GVRT Pre-Test	.25	.25	Skipjack Pre-Test	.25
	Skipjack Familiarization and Practice	.5	.5		
	Skipjack Pre-Test	.25	.25		
2	GVRT Progressive Parts Training	.5	.75	Skipjack Progressive Parts Training	.5
	GVRT Daily Test	.25	.25	Skipjack Daily Test	.25
3	as above			as above	
4	GVRT Variable Training	.5	.75	Skipjack Training	.5
	GVRT Daily Test	.25	.25	Skipjack Daily Test	.25

Table 10 (Con't.)

5	as above			as above	
6	as above			as above	
7	GVRT Pre-Test and Major Test Skipjack Pre-Test and Major Test	.75 .75	.75 .75	Skipjack Pre-Test and Daily Test	.75
8	GVRT Variable Training GVRT Daily Test	.5 .25	.75 .25	Skipjack Training Skipjack Daily Test	.5 .25
9	as above			as above	
10	as above			as above	
11	GVRT Pre-Test and Major Test Skipjack Pre-Test and Major Test	.75 .75	.75 .75	as above	
12				Skipjack Pre-Test and Major Test	.75

Table 10 (Con't.)

13	8 WEEK GAP FOR SCHOOL COURSE						
14	Skipjack	Pre-Test and Major Test	.75	.75	Skipjack	Pre-Test and Major Test	.75

APPENDIX G

Skipjack Error Scoring Circuit

The accompanying diagram describes the error scoring circuit used to measure performance on the Skipjack Simulator. It was designed to provide an error score comparable in principle (though not in numbers) to the combined score provided on the GVRT.

The circuit functioned as follows:

. Depressing "start" button:

1. Starts Problem Timer (via stick relay K3)

2. Lights "problem on" lamp

3. Takes computer out of reset (grounding computer relay through K3 operating and allows integrator to operate).

. Integrator uses greatest of the magnitude of depth or course error and integrates these values. (Output indicated on Meter "M").

. When integrator reaches -100 volts

1. Comparison amplifier "6" slams from zero to 120 volts

2. Relay K1 pulls in

3. Relay K1 makes counter count 1

4. Relay K1 causes relay K2 to pull in

5. Relay K2 opens ground circuit, causing integrator to reset to zero volts.

6. Relay K1 opens after small lag

. When problem timer reaches end of set time:

1. Computer goes into "hold" allowing experimentor to read score.

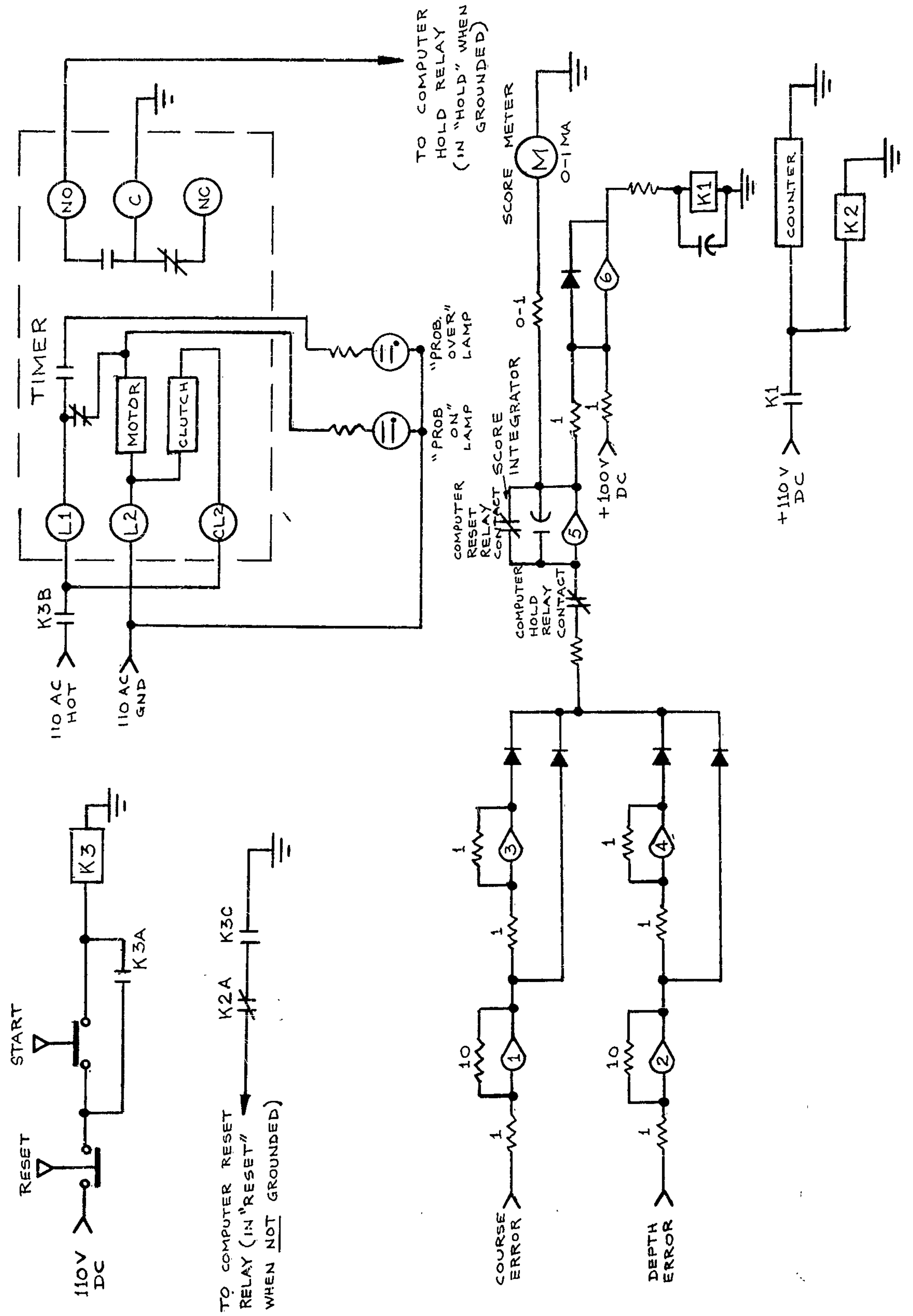

Figure 10 Diagram of Skipjack Error Scoring Circuit

2. Timer motor switch turns off motor and hence turns off "problem on" lamp

3. Same switch turns on "problem over" lamp

. Counter is reset manually

. Depressing "reset" button:

1. Opens power to K3 allowing it to drop out

2. K3 dropping out turns off all lamps on console and opens ground circuit to computer reset relay (thus resetting integrator to zero).

APPENDIX H

Statistical Summary of Study 2

1. Initial Level of Ability

The initial levels of ability of the experimental and control groups on the Skipjack Simulator were compared by means of the scores obtained on the first Skipjack Pre-Test.

Table 11

Skipjack Scores on initial Pre-Test for the experimental and control groups

	Experimental Group	Control Group
Mean Score	28.4	27.8
N	12	8
t	t = .14 (non-significant)	

2. Comparison of the two experimental sub-groups on Skipjack Pre-Tests

From Table 4 it is seen that the two experimental sub-groups are closely similar in their scores for the Skipjack Pre-Test. Table 12 summarizes the differences.

Table 12

Mean differences between experimental sub-groups

	Start	Middle	End
Mean difference	2.8	0.3	0.3
t	t = 1.05 (non-significant)		

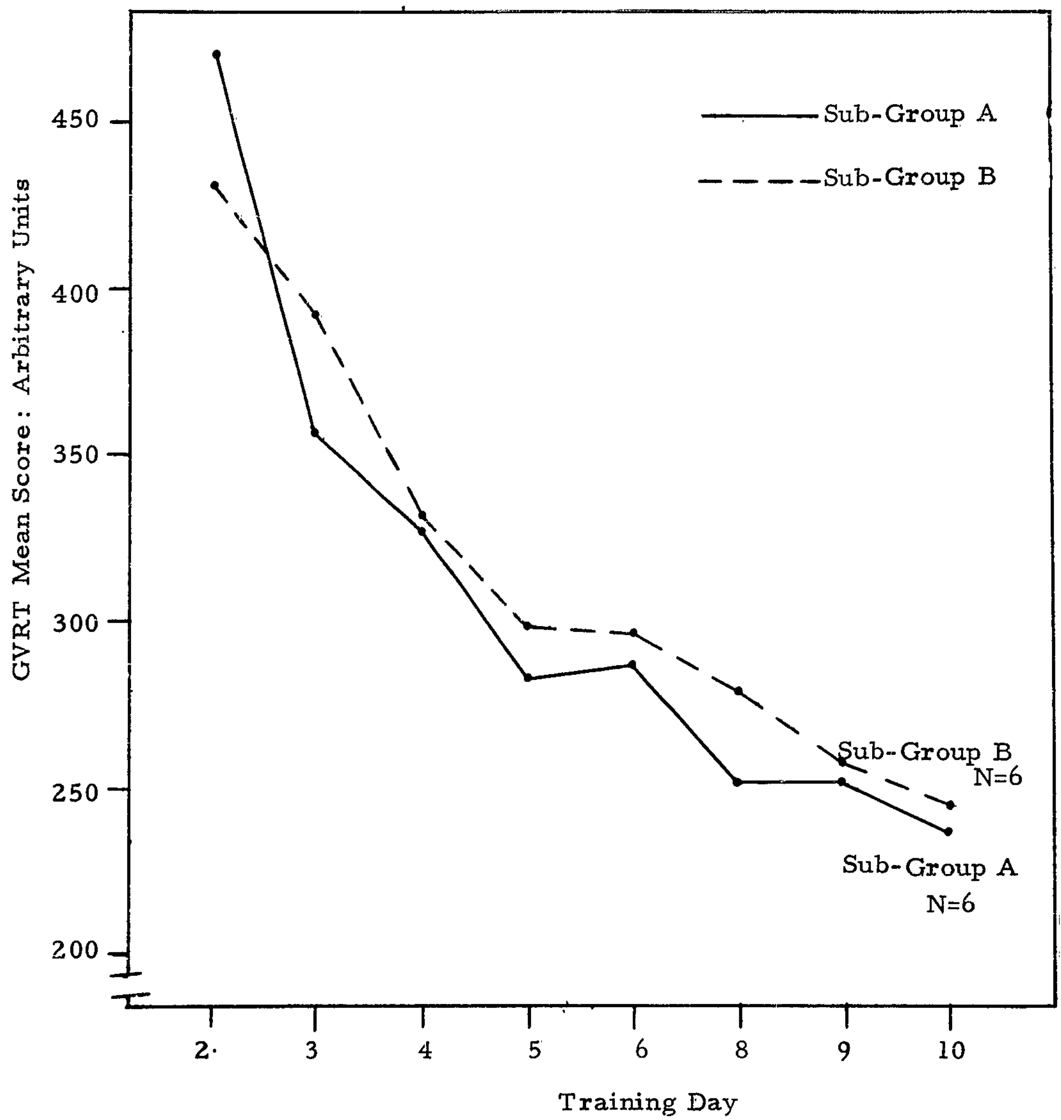

Figure 11 GVRT Learning Curves (Daily Test Scores) of **Experimental** Sub-Groups A **and** B.

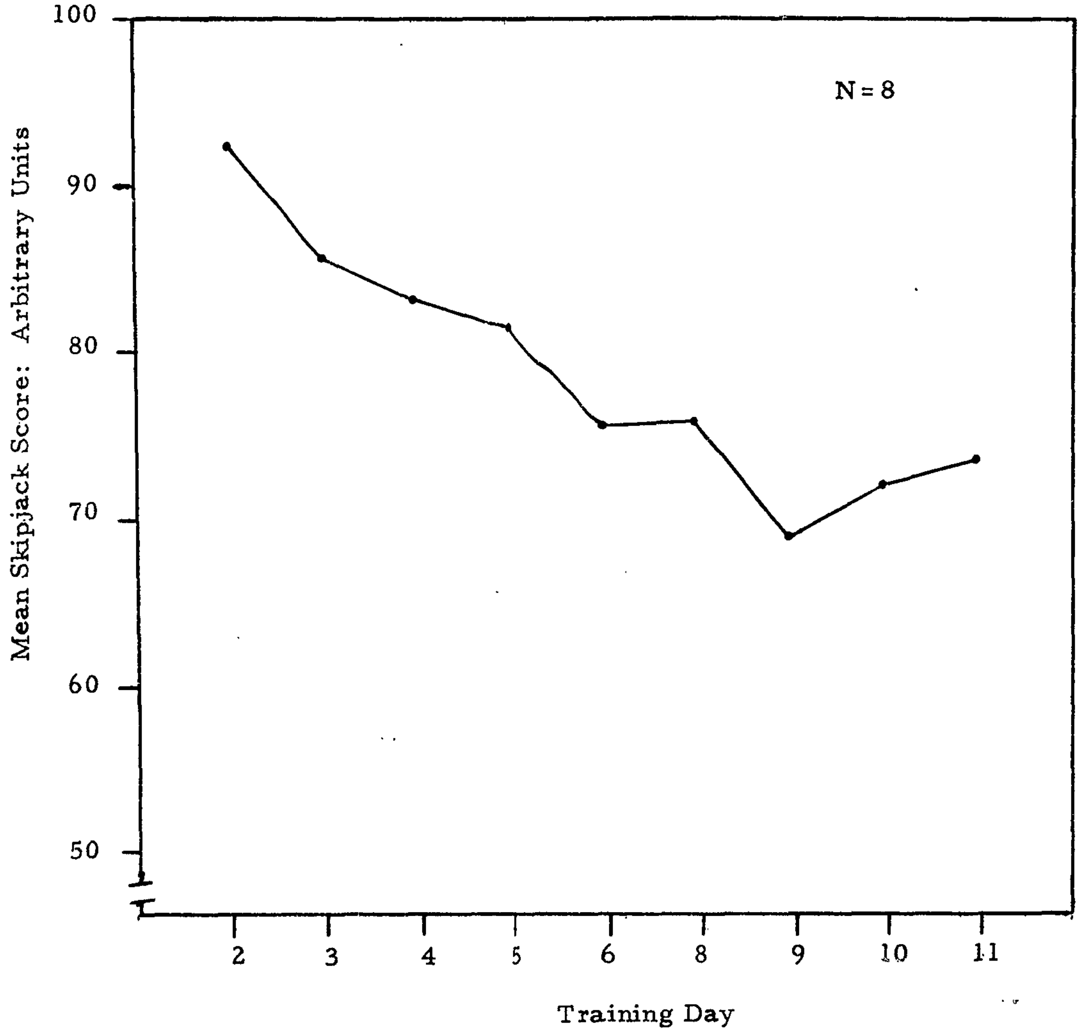

Figure 12 Skipjack Learning Curve (Daily Test Scores) of Control Group

3. Learning Curves on Daily Test of the Two Experimental Sub-Groups and the Control Group

The learning curves for the two experimental sub-groups are shown in Figure 11. These curves are group mean performance curves for the GVRT Daily Test. The two sub-groups are not different from one another. Figure 12 shows the comparable learning curves for the control group for the Skipjack Daily Test.

4. Performance on Major Skipjack Tests

Each group was given a major test on the Skipjack simulator after approximately 4-5 hours and 7-8 hours of direct practice. The scores from these tests form the criterion measures which were analyzed. An analysis of variance was conducted on these scores as shown below. Prior to the analysis it was determined that there was no significant difference in performance between subgroups A and B of the experimental group of 12 subjects. [Mean differences between subgroups A and B on Skipjack Major Test "Middle" was 3.5 ($t = 0.49$) and on Skipjack Major Test "End" was 7.1 ($t = 1.07$)].

The results of this analysis indicate that the effects of training treatments and hours of training are statistically significant. The mean scores for the training treatments show that the group trained on the Skipjack simulator scores better on the major tests than the GVRT trained group. Scores improve with more hours of training. The absence of an interaction term between training treatments and hours of training indicates that the two groups improved over time at a similar rate.

Table 13

Data Summary and Analysis of Variance Table of Skipjack Major Test Performance

	Exp. Groups A & B		Control Group	
	A	B		
Major Test 1	143.45	131.80	91.91	114.48
	139.34	107.54	104.65	95.27
	116.78	142.40	109.47	
	122.16	134.54	112.81	
	116.30	124.19	94.53	
	115.27	133.56	100.64	
Mean	127.28		102.97	
Major Test 2	105.32	115.97	85.10	95.44
	124.70	98.34	93.49	91.62
	97.42	126.51	96.40	
	112.90	112.18	91.82	
	87.91	105.28	94.24	
	107.14	120.12	96.70	
Mean	109.52		93.10	

Analysis of Variance Table

Source of Variance	d.f.	Mean Square	F
Training Methods	1	3981.52	39.38 *
Hours of Training	1	2131.46	21.08 *
Methods X Hours	1	149.15	1.47
Within Cells	34	101.09	
Total	37	9901.41	

$^* p < .01$

Entries in the data table are aggregate scores for each subject over 13 problems of the Major Test. The Major Test nominally contained 20 problems; however, due to various exigencies most subjects failed to complete 20 problems. Reduction of the nominal number of problems in the test to 13 required allocations of scores to missing cells as follows:

- For all entries excluding Major Test #1, Experimental Group B, 25 scores allocated out of total of 442.

- For Major Test 1, Experimental Group B, 2 aggregate scores allocated (note reduction of d.f.'s for within cells variance to account for allocated scores).

Scores were allocated according to the Yates method of iterative solution (16).

The retest data were analyzed separately. Four subjects from the control group and seven subjects from the experimental group were retested at the conclusion of the regular course and 8 weeks after completing the main experiment. Major Test scores between the experimental and control groups significantly differed at $p < .05$ ($t = 2.37$) in favor of the control group. There was no difference between the Pre-Test scores.

APPENDIX I

Student Opinion: Study 2

Ten of the twelve students of the experimental group were interviewed at the completion of their three-week GVRT training period. The following seven questions were posed.

1. Do you feel that your training on the GVRT helped you to control the Skipjack simulator? If so, how? Nine students responded "yes," and one student responded "no."

   a. The "yes" replies included:

      - ". . . . helped familiarize me with the use of the controls. It taught me that I had to keep the rudder and trim angles small. . . in problems that involved high speed. . . .
      - ". . . . gave me a sense of judgment of control. It taught me to anticipate corrections."
      - ". . . . taught me which way to operate the controls to compensate for speed."
      - ". . . . taught me to time the action of the vehicle with the movement of the instruments."
      - ". . . . helped me to control the Skipjack simulator when operating at high speed and using large angles."
      - ". . . . forces the student to watch all of the instruments which is necessary for good control of the Skipjack simulator."

   b. The "no" reply stated:

      - ". . . . the GVRT trainer offered a less involved type of physical control. . . . it seemed like. . . . more of an observation of the movement of the vehicle on the GVRT . . . . while the Skipjack gave the human effect of being in the vehicle while testing."

2. What skills did you find most difficult to learn or acquire on the GVRT?

   - Basic manipulation of the control stick.
   - Ability to anticipate stick corrections (3 students).
   - Development of a good scanning technique.
   - Stopping the oscillation of the vehicle at high speeds (3 students).
   - Control of unstable problems.
   - Control of high-speed problems with initial heading or pitch angles (2 students).

3. What skills did you find most difficult to learn or acquire on the Skipjack? Do you think you would have had more difficulty acquiring these skills not having had training on the GVRT?

   - Two students stated depth error was most difficult.
   - Two students stated course error was most difficult; one student associated the difficulty only with high-speed problems (30-40 knots).
   - Eight students found both depth and course error equally difficult, mentioning in addition:
     - Scanning of the various displays
     - High-speed problems (3 students)
     - Large critical turn angles
     - Anticipation of the mechanical movement

   All answered affirmative to the second part of the question with one student saying that only one-third of the training time was necessary.

4. What type vehicular problems encountered on the GVRT were most helpful to you with the control of the Skipjack?

   - High-speed unstable problems with turbulence (7 students).

- Problems with initial pitch and/or heading angles (6 students).

5. Do you think the GVRT was effective in teaching you eye-hand-coordination skills necessary for the control of the Skipjack? All students answered "yes," and some made the following comments:

   - ". . . . the GVRT didn't allow the trainee to use both hands. . . . most vehicular craft have to have the use of both hands for proper manipulation."

   - ". . . . I started to scan the gauges and work the controls all in one movement in a few sessions."

   - ". . . . I think it was very effective in that area. In order to control the GVRT, you must constantly be moving the stick and watching the gauges."

   - ". . . . the GVRT provided an effective gauge arrangement for becoming accustomed to quick check scanning of the scales on all problems."

6. Do you have any suggestions for improvement of the GVRT?

   - All ten people were satisfied with the device.

7. Did you enjoy your training on the GVRT? All ten subjects answered "yes," and in addition, some students made the following comments:

   - "I got a great deal of enjoyment out of the chance to be able to improve my coordination and better understand the type of training such a simulator can offer."

   - "It was a good challenge and made the Skipjack simulator easier to handle."

   - "It proved interesting and different."

   - "I enjoyed the training very much. I think that it will be of some help to me in the future. I also think that everyone training for submarine duty should have a chance to operate it (GVRT)."

Eight students, without prompting, returned during their eight-week course and said they had no trouble controlling course and depth aboard the Askania trainer and actual submarines. They felt they were somewhat superior in performance to the rest of the class.

The eight members of the control group were interviewed in a similar fashion. No information significant to the study or contrasting with the experimental group's responses was given.